

ROOSEVELT WILD LIFE
ANNALS





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Fig. 1. Red squirrel at a feeding station. Photograph by A. A. Allen

ERRATA

Page 16, line 25: Delete the sentence beginning with "The average of seven specimens....."

Page 44, paragraph 5, lines 4, 5, 6 read: (5) red spruce swamp; (6) white pine stand; (7) pine and gray birch; (3) Scotch pine plantations over ten years old; (9) hardwood swamp; (10) the edificarian habitat.

Page 59, line 4. Read: None of them being produced by the teeth.

Page 96, line 24. Read: Klugh ('27, p, 16).

Page 136, 4th line from bottom: Miko, not "Mike".

THE RED SQUIRREL: ITS LIFE HISTORY AND HABITS, WITH SPECIAL REFERENCE TO THE ADIRONDACKS OF NEW YORK AND THE HARVARD FOREST

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INTRODUCTION

The red squirrel is found over one-half the land area of America, north of the Rio Grande. In all this vast domain this animal fills a place in nature that doubtless is of importance now, has been in the past and will continue to be long into the future.

The red squirrel's fur is of little use, and its flesh is, perhaps, to us, of still less importance. It is by reason of an undeniable æsthetic attraction and its biotic interest rather than because of its economic status, perhaps, that the red squirrel has long held the attention of the naturalist, the nature essayist and the layman.

* Assistant Curator of Mammals, American Museum of Natural History, New York City.

Commonly the squirrel hails the intruder on its domain with volleys of chatter, and is only exceptionally moved to retreat and to hide. The extraordinary behavior and the handsome appearance of this denizen of the forest account for the fact that it is well known where equally common small mammals are entirely overlooked. The opinions of people, are, however, anything but unanimous when the status of the squirrel in relation to the community at large is considered. Some see in this impetuous creature only a vivacious forest sprite whose sole claim to existence lies in its charming disregard for all ordinary customs and civilities of life. Others see the squirrel as a destroyer of vast quantities of buds and seeds, a creature barking trees, robbing birds' nests, and driving the more desired gray squirrel from its territory; an animal of little interest as game; a rodent perhaps best dispensed with. Others again note the squirrel burying seeds and nuts for use in the season of scarcity and conclude that, though all unconsciously, it is actually aiding in natural reforestation. Somewhere among these various and conflicting views lies the truth. Like all other wild creatures, the red squirrel has a myriad relations with its environment, some of which are of benefit to man's community as a whole, some suit the interests of but a few, and others are in themselves wholly undesirable. For this reason the red squirrel is alternately denounced and defended. In the many accounts of the red squirrel which have been printed, both sides have been presented, but few have given both sides without bias.

The lack of known facts concerning the biology of the red squirrel becomes apparent upon a compilation of the literature. Many accounts of its life are confined to generalizations, interesting, but valueless because of the lack of supporting facts. Others are insufficient in detail because their authors relied upon nebulous memory for their manuscripts. Some writers have sacrificed facts to fit a narrative. Fortunately there are a few excellent accounts on the red squirrel, and numerous carefully recorded scattered observations.

It has been attempted here to bring together the principal facts regarding the life and habits of the red squirrel, as gathered from the literature, and to supplement this with my own observations recorded during a special study of the species, sponsored jointly by the Roosevelt Wild Life Forest Experiment Station of the New York State College of Forestry, and the Harvard School of Forestry. This study was limited territorially to the Adirondack forests of New York, and the Harvard Forest at Petersham, Massachusetts. These areas are inhabited respectively by the red squirrel races *Sciurus hudsonicus gymnicus* and *S. h. loquax*, the ranges of which meet somewhere in the intervening region. In addition to my observations made on these two forms, other personal records made in other parts of the range of the red squirrel are drawn upon. Free use has been made of available literature on the species for, though its range on the Continent is very great, the habits of the species as represented by its several races or subspecies have much in common, and traits revealed by one form may, at least in similar situations and conditions, be looked for in the others. The attempt has been made to make the account of the life and habits of the red squirrel as complete as possible. All quotations from the writings of others have been cited in the text. Study in several areas within the territory selected was found desirable in order to develop a breadth of view essential to the fair consideration

of the forest relations of the red squirrel. Such a viewpoint would not be gained by seeing one particular set of local conditions alone, nor by watching the animals in but one type of forest. Habits of the squirrels vary from place to place, depending no doubt on the difference in food, enemies, and habits developed from normal speciation. With more than one group of squirrels under observation conclusions drawn are less likely to become invalidated by observations made in other localities.

The summer of 1925, from June 20 to September 12, was spent in the Harvard Forest at Petersham, Worcester County, Massachusetts. The summer of 1926 was spent in the Adirondack region and on Valcour Island, Lake Champlain. The following was my itinerary for the period: June 10 to 26, Speculator; June 26 to July 7, Piseco; July 8 to 10, Old Forge; July 11 to August 5, Long Lake; August 6 to 7, Saranac Lake; August 8 to 17, Lake Placid; and August 18 to September 12, Valcour Island, Lake Champlain.

The localities examined presented several sets of conditions. In the Harvard Forest the squirrel represented was, as previously stated, most nearly allied to *S. hudsonicus loquax*, and in the Adirondacks and on Valcour Island the form was considered to be *S. h. gymnicus*. In the Harvard Forest the tree with which the squirrel was most associated was the white pine. The habitats in which it resided here were: white pine; white pine, hemlock and transition hardwood; hemlock; and red spruce swamp. In the Adirondacks the habitats available were more diverse. During the summer, however, the squirrels were almost invariably associated with red spruce or with balsam. But rarely were they seen in hardwood forests, and even then a conifer was certain to be nearby. On Valcour Island, red spruce, white spruce, and balsam were all closely correlated with the local distribution of the red squirrels. This Island was found a particularly suitable place to study the species. Gray squirrels, chipmunks, porcupines and deer are lacking on the Island, though present on the adjacent mainland. Hence there were no mammals, with the possible exception of flying squirrels, whose workings could become confused with those of the red squirrel. Further, the squirrel population was at a peak, due to the absence or rarity of the larger carnivores and of hawks and owls, as well as to the lack of competition for food with the gray squirrel and the chipmunk.

Field notes were made following personal observations of free living as well as caged individuals. Nests, burrows, middens, and temporary feeding places were described at the hour of observation. A number of squirrels were shot and trapped for notes on anatomy, embryology, food and parasites. Caged specimens were kept for feeding observations.

It is a pleasure to acknowledge here my indebtedness to Dr. Charles C. Adams, Dr. Charles E. Johnson and Mr. W. A. Dence of the Roosevelt Station for their unselfish cooperation in the conduct of this investigation. I am further indebted to Professor R. T. Fisher, Mr. A. C. Cline and Mr. Neil Hosley of the Harvard Forest for numerous courtesies extended during the work at Petersham. During the course of field investigations many others contributed generously of their time and help. I wish to thank particularly among these, Messrs. Henry Seton, Charles Bonesteel, George Hudson, Edward Butler, Andrew Magee, Emerson Nye, Harold Graham and Isaac Robinson.

To Dr. H. E. Ewing, of the United States National Museum, I am indebted for the determination of parasites, and to Dr. Vera K. Charles of the Bureau of Plant Industry I extend my thanks for identifying the fungi mentioned in this paper.

NOMENCLATURE AND SYSTEMATIC ACCOUNT

Nomenclature. Throughout its wide range *Sciurus hudsonicus* is known to the English speaking population as the red squirrel. But the Indian tribes of North America first gave names to the creature, and some of these may be found recorded in the literature, namely:

Ad-jee-dah-mó ("tail-in-air"); Ojibwa, Sauteaux, Muskego, Cree (Seton, '09, p. 307); Adjidomo (Klugh, '27, p. 1); Ahjiduhmo (Bailey, '26, p. 46);

Kléé-ay, Chipewyan (Seton, '09, p. 307);

Kee-hah-chah, Yankton Sioux (Seton, '09, p. 307);

Zeé-cha, Ogallala Sioux (Seton, '09, p. 307);

Kí-gu-ik, Eskimo (Nelson, '87, p. 280);

Pillilooeet [for Douglas Squirrel], (Finley and Finley, '25, p. 142).

The early French Canadians followed with the name "l'Écureil rouge" (or roux of Diome, '02, p. 73), the meaning of which is the same as that of our "red squirrel."

The early settlers in New England gave to this species the name red squirrel and also, in addition, in allusion to one of its most common vocal efforts, the name chickaree. At Black Mountain, North Carolina, in the most southern part of its range, the red squirrel was, in the past century at least, known as the "mountain boomer" (Audubon and Bachman, '49, p. 130), a name which has apparently been carried to the west coast and corrupted to "bummer" squirrel, in reference to *S. douglasii albolimbatus* (Grinnell and Storer, '24, p. 204). The name of barking squirrel (Schoolcraft, '21, p. 273) appears to have been in use in some localities in the early part of the last century. Mountain squirrel is given by Kennicott ('57, p. 67) as a common name for this species.

In the Rocky Mountains the various forms of the red squirrel are usually known as pine squirrels.

From 1771 to the present day a long array of book names has been bestowed upon the chickaree and its subspecies, but these have never come into common use, either by the layman or by the scientist, and are therefore quite useless. Among such names are Hudson Bay squirrel, l'Écureil rouge, or de la Baie d'Hudson and other variations. Likewise we find the names of certain popular subspecies such as Black Hills chickaree, Streater's chickaree, and so on. The closely related species *S. fremonti* and *S. douglasii*, while almost universally called pine squirrels throughout their ranges, are given in our books such names as Redwoods chickaree, Taos chickaree, etc.

Systematic account. The red squirrel is classified in the Order Rodentia, superfamily Sciuroidea, family Sciuridae, and subfamily Sciurinae. With all true tree squirrels it is placed in the genus *Sciurus* (from Gr. *Skiauros* or squirrel; literally "shade-tailed", from Gr. *Skia* shade+*oura*, tail, in allusion to the animal's

habit of sitting as it were in the shade of its own tail). In common with the closely related species *S. fremonti* and *S. douglasii* it is placed in the subgenus *Tamiasciurus* (from Gr. *Tamias*, a steward, or one who lays up stores, + *Sciurus*). The specific name now established for the red squirrel is *Sciurus hudsonicus*:

Sciurus hudsonicus (Erxleben)

1777. [*Sciurus vulgaris*] *hudsonicus* ERXLEBEN, Syst. Regn. Anim., Vol. 1, p. 416.
1885. *Sciurus hudsonicus hudsonicus* TRUE, Proc. U. S. Nat. Mus., Vol. 7 (1884), p. 595, 1885. (Part.)
1894. *Sciurus hudsonicus* ALLEN, Bull. Am. Mus. Nat. Hist., Vol. 6, p. 325, Nov. 7, 1894.

A complete survey of the history of the scientific nomenclature of this species may be obtained by reference to Allen ('77, pp. 672-673; and '98, p. 255).

The species *Sciurus hudsonicus* while everywhere recognizable as a red squirrel has, as is to be expected in such a wide ranging species, undergone modifications in several lines, to which subspecific names have been assigned. The various subspecies with their type localities recognized at this writing are herewith listed. Since to many individuals interested in our common mammals systematic descriptions of the subspecies of the red squirrel are not readily available, it is felt that the usefulness of this publication would be increased by giving their respective ranges as at present generally defined.

Sciurus hudsonicus hudsonicus (Erxleben)

Type Locality. Hudson Strait.

Range. The coniferous forest area of America north of the St. Lawrence and Ottawa Rivers, Georgian Bay, Lake Superior and the United States—Canadian border west to the Pacific, except for the Turtle Mountains and the Red River Valley of North Dakota and Minnesota, where its range extends southward; the Southern Canadian Rockies, the coast and coast mountains of British Columbia and Southern Alaska, where other forms take its place. Along its southern and western limits it intergrades with subspecies of adjacent areas. In Alaska it reaches the shore of Bering Sea at the head of Norton Sound and on the Kadiak Peninsula near Bering Strait. In Interior Alaska it reaches latitude 69°.

Size. Allen ('98, p. 255) gives measurements, the average of six adult specimens from Fort Simpson, Mackenzie Territory, Canada, as follows: Total length 317 (305-333) mm; tail vertebrae 116 (92-134) mm; and hind foot 46 (43-47) mm.

Winter Pelage. A broad median band of rufous above, extending from the top of the head nearly to the end of the tail; the sides of the body and the outer surface of the limbs to the toes are olivaceous gray; the ear tufts are dusky, the hairs slightly tipped with rufous; the belly, the inner surface of the legs, the throat, chin, lips and eyelids are a grayish white; tail above with a broad central area of yellowish rufous, bordered with a band of black, widening at the tip into a broad subterminal bar; below, the central area is yellowish gray.

Summer Pelage. Whole upper surface, including flanks, pale yellowish rufous; ventral surface, lips and eyelids pure white; a conspicuous black lateral line separating the two surfaces; ears like the back and without tufts; tail colored nearly as in winter.

Sciurus hudsonicus gymnicus Bangs

Type Locality. Greenville, near Moosehead Lake, Piscataquis County, Maine.

Range. From the St. Lawrence River south to the southern boundaries of Maine, New Hampshire, Vermont, and the Adirondack Mountains.

Size. Smaller than *S. h. hudsonicus*. Hind foot small. Average measurements of 10 specimens from Digby, Nova Scotia, 9 from Amherst, N. H., and 5 from South Twin Lake, Me. (Allen, '98, p. 255): total length 290 mm; tail vertebrae 115 mm; hind foot 45.5 mm.

Winter Pelage. Back and upper side of tail bright chestnut; sides olive gray; under parts grayish white.

Summer Pelage. No distinct rufous area on the back; under parts pure white; black lateral stripe.

Sciurus hudsonicus loquax Bangs

Type Locality. Liberty Hill, New London County, Connecticut.

Range. The deciduous and mixed coniferous forest area from Massachusetts, Southern Ontario and the south shore of Lake Superior to Central Illinois, Indiana and Ohio, south through Virginia in the Alleghenies and through Maryland along the coast.

Size. A large form. Average of eight specimens from the type locality (Bangs, '96, p. 161): total length 318.3 mm; tail vertebrae 133.5 mm; hind foot 47.42 mm. The average of seven specimens from Roan Mountain, N. C., (Allen, '98, p. 257); total length 340 (319-356) mm; tail vertebrae 139 (127-152) mm; hind foot 35.6 mm to 45.7 mm.

Winter Pelage. In general, much darker than *S. h. hudsonicus*. Median dorsal band darker red and broader; white of the under parts only slightly and inconsistently vermiculated with black.

Summer Pelage. Markedly brighter and redder than in winter.

Sciurus hudsonicus abieticola. A. H. Howell.

Type locality. Highlands, North Carolina.

Range. The higher mountains of North Carolina.

Size. The average of seven specimens from Roan Mountain, North Carolina, (Allen, '98, p. 257): total length 340 (319-356) mm; tail vertebrae 139 (127-152) mm; hind foot 35.6 mm to 45.7 mm.

Pelage. "Similar to *S. h. loquax*, but distinctly darker on head and sides, and the red of dorsal area a deeper shade; underparts in winter more grayish (less clear white) and more or less vermiculated with dusky." (Howell, '29, p. 75.)

Sciurus hudsonicus minnesota Allen

Type Locality. Fort Snelling, Hennepin County, Minnesota.

Range. Central and Southern Minnesota, Western Wisconsin and Eastern Iowa.



Map 1. Distribution map of the forms of the sub-genus *Tamiasciurus*. The stars indicate the type locality of each sub-species. (*S. h. abieticola* Howell, of North Carolina, recognized as distinct after this paper was in press.)

Size. Average of twenty topotypes (Allen, '98, p. 257): total length 334 (297–356) mm; tail vertebrae 130.2 (118–146) mm; hind foot 49.9 (47–52) mm.

Pelage. Differing from *S. h. hudsonicus* principally in the under side of the tail being all gray instead of rusty red.

Sciurus hudsonicus dakotensis Allen

Type Locality. Squaw Creek, Black Hills, Custer County, South Dakota.

Range. Black Hills of South Dakota and adjoining portions of Wyoming (Allen, '98, p. 260).

Size. The largest of all forms. Average of five specimens (Allen, '98, p. 260): total length 346 (338–356) mm; tail vertebrae 145 (143–149) mm; hind foot 51 (50.8–53) mm.

Winter Pelage. Median dorsal band light yellowish rufous; rest of upper parts and outside of limbs and feet yellowish gray; ventral surface clear white.

Summer Pelage. Pale yellowish olivaceous gray. Feet, outside of shoulders and edge of thighs, yellowish rufous; lateral line obsolete; ventral surface pure white; tail much lighter than in *S. hudsonicus* and in *S. h. loquax*.

Sciurus hudsonicus baileyi Allen

Type Locality. Bighorn Mountains, Washakie County, Wyoming. Altitude, 8,400 feet.

Range. Outlying mountain ranges of Central Wyoming and Eastern Montana and northward into Alberta in the eastern foothills of the Rocky Mountains. Its range includes the Bighorn, Pryor and Laramie Mountains in Wyoming, and the Big Snowy, Bear Paw and Little Rocky Mountains in Montana, and probably other outlying pine-covered buttes and hills (Allen, '98, p. 262).

Size. The average measurements of twenty-one specimens are (Allen, '98, p. 261): total length 336 (313–359) mm; tail vertebrae 136 (121–153) mm; hind foot 51 (49–53) mm.

Winter Pelage. Dorsal surface a pale yellowish gray, with a broad median reddish band.

Summer Pelage. Yellowish olivaceous above; feet ochraceous orange to reddish orange; a distinct black lateral line separating the dorsal surface from the ventral, which is white, usually washed with fulvous; upper surface of the tail a grizzled red and black.

Sciurus hudsonicus ventorum Allen

Type Locality. South Pass City, Wind River Mountains, Fremont County, Wyoming.

Range. Wind River Mountains region and northward along the eastern base of the Rocky Mountains at least to Mystic Lake, and probably to the Belt ranges east of Helena, and thence westward to the head of the Snake River in Idaho, and south along the Idaho and Wyoming boundary to the Wasatch Mountains in North-eastern Utah. Its range thus includes not only the Wind River and Gros Ventre Ranges, but the Shoshone and Beartooth Mountains, the whole Yellowstone National Park region and the outlying ranges east of the Main Divide to Central Montana; to the westward and southward it includes the Snake River, Cariboo,

Thompson, Blackfoot, Bear River, Bannock and Wasatch Ranges with their outlying and included or connected spurs (Allen, '98, p. 263).

Size. The average measurements of twenty specimens of this form as given by Allen ('98, p. 263) are: total length 329.5 (300–350) mm; tail vertebrae 133.6 (121–145) mm; hind foot 51.5 (49–55) mm.

Winter Pelage. Narrow median dorsal band of dark rufous, narrower and less dark than in *S. h. richardsoni*, but much darker and less yellowish than in *S. h. baileyi*; rest of dorsal surface, legs and feet, gray, suffused with yellowish. A dusky, though obscure, lateral line.

Summer Pelage. Nearly uniform dark olivaceous above; sides of shoulders and outer edge of thighs heavily suffused with strong reddish fulvous; upper surface of feet ochraceous; lateral line indistinct.

Sciurus hudsonicus richardsoni (Bachman)

Type Locality. Head of the Big Lost River, Fremont County, Idaho.

Range. Western border of Northern Montana, Central and Northern Idaho, Northeastern Oregon, Northeastern Washington and thence northward into Southeastern British Columbia—in other words, the Bitter Root and Coeur d'Alene Mountains on the western border of Montana; the Lost River, Salmon River, Pahsimeroi and Sawtooth Mountains in Central Idaho, and westward in the Craig and Seven Devils Mountains to the Powder River and Blue Mountains of Oregon, thence through Northern Idaho, and west in the mountains of Northeastern Washington to Coville, and northward into the Kootenai District of Eastern British Columbia. The extent of its range northward along the main Rocky Mountains cannot now be determined, owing to absence of material from the area in question. It appears to reach its maximum of differentiation in the Coeur d'Alene and Bitter Root Mountains, although specimens from Central Idaho (the type region) are scarcely distinguishable (Allen, '98, p. 266).

Size. Forty-nine specimens averaging a total length of 338 (316–353) mm; tail vertebrae 133.6 (120–148) mm; and hind foot 51 (47–54) mm. (Allen, '98, p. 265).

Winter Pelage. A broad median dorsal band of chestnut rufous; rest of upper surface a dark gray with a fulvous wash; tail with a narrow central area of dark rufous, extending about half the length of the tail; the rest of the tail an intense black; black lateral line generally prominent; under parts grayish white, vermiculated with black; the apical halves of the tufted ears black.

Summer Pelage. Uniform rufous olivaceous above; feet, forearms, shoulder and lateral surface of hind limbs ochraceous to reddish orange; black lateral line strongly developed; ventral surface pure white; tail with a narrow deep reddish central area above, over one-half to two-thirds its length; rest of the upper surface of the tail black.

Sciurus hudsonicus streatori Allen.

Type Locality. Ducks, British Columbia, Canada.

Range. Central part of Northern Washington from Columbia River northward over Central British Columbia. It occupies the Okanagan District of Washington, from the head of Lake Chelan northward. At Lake Chelan and Fort

Spokane it meets *S. douglasii* without intergrading; at Marcus and Conconully it intergrades with *S. h. richardsoni*, which occupies the area immediately to the eastward, as it does also in the Kootenai District in Southeastern British Columbia (Allen, '98, p. 268).

Size. Forty-nine specimens averaged: total length 320 (280–355) mm; tail vertebrae 124.5 (100–141) mm; hind foot 50.9 (49–54) mm. (Allen, '98, p. 268).

Winter Pelage. Similar to *S. h. richardsoni* except that the median dorsal band is vermiculated with black, the lateral line is generally wanting or obsolete and only the terminal fifth of the tail is black.

Summer Pelage. Similar to *S. h. richardsoni*. The general color is more olivaceous and less rufous. The black portions of the tail are greatly reduced. There is a broad black lateral line.

Sciurus hudsonicus vancouverensis Allen

Type Locality. Duncan Station, Vancouver Island, British Columbia, Canada.

Range. Vancouver Island and the coast region of Northern British Columbia.

Size. The average measurements of thirty-two specimens (Allen, '98, p. 270, and Swarth, '12, p. 88) are: total length 303 (280–325) mm; tail vertebrae 114 (92–130) mm; hind foot 49.6 (45–52) mm.

Winter Pelage. Resembling *S. h. richardsoni* except that the black area of the tail is smaller. Underside gray with a brownish tinge to brownish, vermiculated with dusky. Center of tail on ventral surface decidedly grayish.

Summer Pelage. Dark olivaceous, sometimes tinged reddish above; white below, with a tinge of fulvous, or a strong wash of pale yellow.

Sciurus hudsonicus picatus Swarth

Type Locality. Kupreanof Island, 25 miles south of Kake Village, at the southern end of Keku Straits, Southeastern Alaska.

Range. The Sitkan district of Alaska, including the mainland, from Juneau to British Columbia and the islands between the same regions north of Summer Strait and east of Clarence Strait. The squirrels have not invaded such outlying islands as Prince of Wales and Dall.

Size. Sixteen specimens averaged: total length 310.3 (292–321) mm; tail vertebrae 124.2 (114–132) mm; hind foot 51 (46–55) mm. (Swarth, '12, p. 88).

Pelage. Intermediate between *petulans* and *vancouverensis*. Color darker than *petulans*, brighter than *vancouverensis*; fairly well defined bright hazel dorsal stripe; black lateral stripe more prominent than in *vancouverensis*; tip of tail less extensively black than *vancouverensis*; center of tail reddish below, nearly as bright as the upper.

Sciurus hudsonicus petulans Osgood

Type Locality. Glacier, White Pass, Southern Alaska. Altitude 1,870 feet.

Range. Probably through the coastal mountains from Juneau to Yakutat Bay.

Size. The average measurements of two specimens from the type locality are: total length 303 mm; tail vertebrae 720 mm; hind foot 550 mm. (Osgood and Bishop, '00, p. 27).

Winter Pelage. Similar to *hudsonicus* but darker; mid-dorsal line diffuse; tail darker.

Summer Pelage. Above, from raw umber to Prout's brown of Ridgeway. Fore legs and feet russet; black lateral line prominent; under parts lightly washed with fulvous; tail hazel above; sub-terminal black limited; under surface of tail paler than upper.

Sciurus fremonti and its subspecies are found in the Rocky Mountain Chain and outlying ranges of Colorado, New Mexico and Arizona, and in a small part of the eastern border of Utah.

Sciurus douglasii and its subspecies are found in the Cascades, Sierra Nevadas and the coast ranges of Washington, Oregon and California.

PELAGE

Protection. The pelage of the red squirrel is of significance in its concealing coloration. Though the red squirrel in motion is often a conspicuous object, the red squirrel at rest is practically obliterated by its background. Viewed from above the dark coat presents a color and shade which harmonizes well with the most common backgrounds of the animal, namely, tree limb, forest floor, or stone wall. The tail being in most cases uniformly colored above and below does not alter the picture by its varying positions. From below, the white or light gray ventral body surface is rendered inconspicuous by the broken sky of the forest roof, against which it is most commonly seen. Thayer has characterized this type of coloration as complete oblitative shading.

Age Variation. There is a considerable variation in the coat color of specimens taken in one locality at any one time of the year. These variations are correlated with age, moult, and genetic individuality.

Variation due to age is strikingly displayed in summer. In the Southern Adirondacks, during early July, the young squirrels were a brilliant rufous on the back and flanks, while adults were on the whole more olivaceous. One large and presumably old individual seen July 3 was a distinct gray along the flanks. This variation may be due to the older squirrels losing their winter coat more slowly than do the young of the year; or it may be because the squirrels are born in summer pelage. Probably it is due at least in part to an actual age difference in coat color. Allen ('98, p. 253), working with a large series of museum skins, was, however, unable to discover any correlation between size and color.

Mearns ('98a, p. 340) states that the young, "born early in the season, during cold weather, are coated with the winter pelage and have red backs and grayish limbs, but those born in hot weather are at once provided with the summer coating." This strange observation has not been verified.

Seasonal change. The seasonal change in color is due to an actual replacement, twice a year, of the hairs of the body. There is no change in color of the hairs themselves, nor a mere overgrowth of hairs of a different color, as has been shown by Allen ('90, p. 44). The process is a very gradual one, there being no short period in which the coat changes quickly.

The ears in winter bear short tufts of black hairs, which in summer are lost and replaced by shorter reddish hairs. This change, too, is but relative, for an

immature female taken July 25, at Long Lake, New York, had ear tufts strikingly prominent, while others taken at the same time displayed none. Ear tufts on a pair of captives in New York City reached their maximum development the second week in December.

The soles of the feet are heavily furred with soft hairs except over the tubercles at the base of the toes. In summer the soles of the feet are naked, often as far as the heel. The winter furring of the feet is more complete to the northward and is probably an aid in traversing the soft snow and in conserving of body heat.

The winter pelage is thicker, longer, and softer than that of the summer. The hairs of the tail, which serve as an important blanket for the resting squirrel, exhibit this difference strikingly.

The winter coat begins to show wear and thinning in late April and May, though there is little color change at this time. Through June and July the moult continues until by early August the change is complete. The summer coloration reaches its highest intensity in September and October. Then the coat is reddest and the lateral line blackest.

The autumnal moult starts in November, in Southern New York, and while complete by the end of December, the color of the coat does not reach its peak of intensity until February or March. Then the broad rufous dorsal band is most distinct and the black lateral line least so. A month later the cycle starts anew.

The seasonal color change occurring in *S. h. hudsonicus* is less than in *S. h. loquax*, according to Adams ('09, p. 401).

Melanism. Melanism is, according to Allen ('98, p. 273) and Bell ('98, p. 78), extremely rare. Allen records (op. cit., p. 273) an example in winter pelage from Nulato, Alaska, that is entirely and intensely black. In a district on the south coast of New Brunswick, according to a report published by Adams ('73, p. 99), the entire red squirrel population is black.

Albinism. Albino red squirrels are frequently reported. Pennant (1792, p. 134) refers to "Sir Ashton Lever being possessed of a specimen of milky whiteness." Seton ('09, p. 311) records that Paul Doherty observed a pair of albinos at Woodstock, N. Y. Several pure albinos and also one that was pure white, except for a brownish dorsal stripe and the tail, have been taken in Washtenaw County, Michigan, according to Wood ('22, p. 18). A pair from Wheeler, Michigan, is mentioned by Dunn ('21, p. 130). A race of perfect albinos, Mearns ('98a, p. 340) writes, was bred through several generations on Constitution Island in the Hudson River, during the seventies. Several were killed and preserved as specimens. MacFarlane ('05, p. 749) gives the record of another specimen from Northwest Territory.

A family of one adult and three young captured in Erie County, New York, were all albinos except one of the young (Miller, '99, p. 304).

It is probable in view of these records that this albinism of the red squirrel is genetically dominant to the normal or agouti coloration, but that in nature, unless the individuals be geographically isolated, the albinos would be more quickly killed off than the others and would not for long perpetuate their kind.

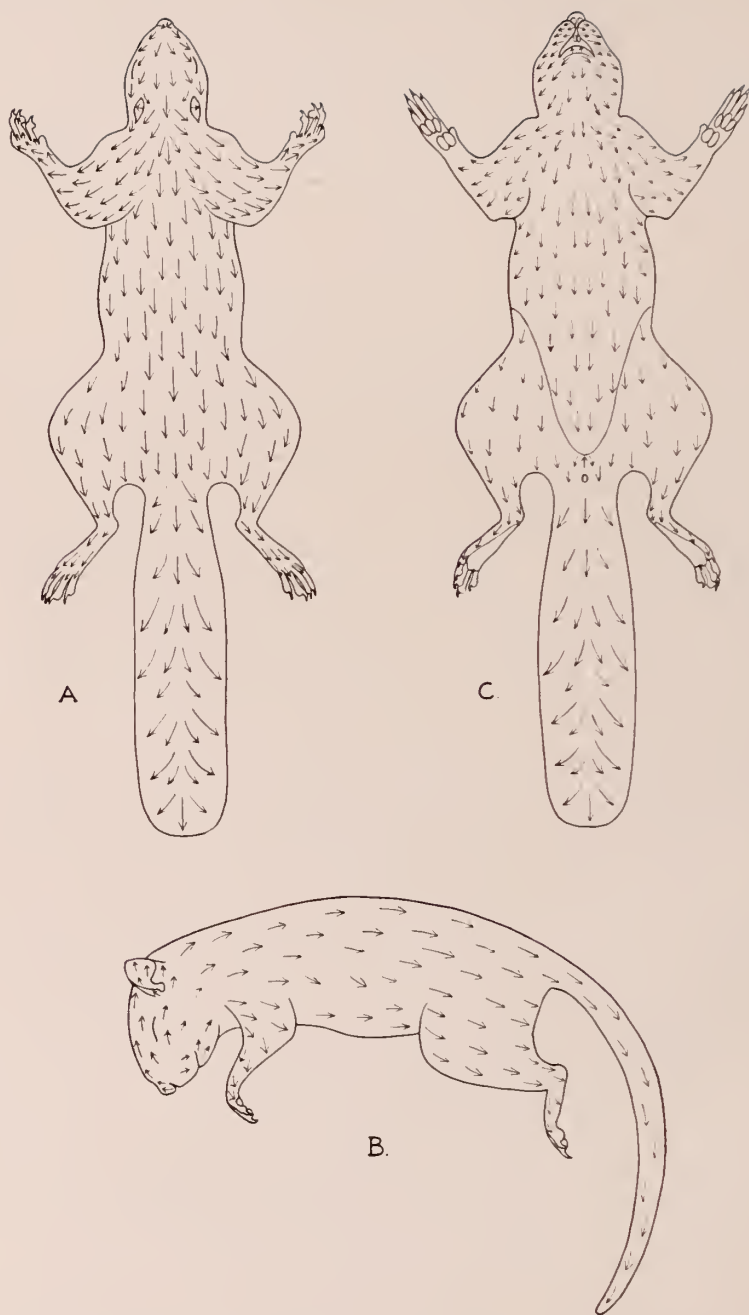


Fig. 2. Direction of hair growth in the red squirrel (*S. h. gymnicus*). A, dorsal surface; B, lateral surface; C, ventral surface; vibrissae omitted.

A partly albinistic red squirrel taken during July in Charlevoix County, Michigan, is described by Dice ('25, p. 30): "This specimen is slightly paler than the normal, having numerous white hairs distributed through the pelage especially on the head. The tail is nearly all white and is pure white on the end, but towards the base of the tail the hairs become gradually more and more brownish at their bases. The sides and soles of the hind feet have considerably more white than normal but the front feet are almost normal."

Seton ('28, p. 118) gives on the authority of Capt. George Eisenhard a case from Culver, Indiana. He writes: "In 1916 a white-tailed, i. e., part albino, Red Squirrel, lived in a big oak by the mess hall in Culver. She mated with an ordinary Red Squirrel. In August, the young — 4 or 5 — were seen running with the mother. All had white tails which seemed to prove their ruin; for the cats killed them one by one."

Another case of partial albinism is described by DeKay ('42, p. 62). This squirrel was from Northern New York: "The whole upper part of the head and body, with the exception of a large reddish spot on the left flank was of a light ash gray; the reddish spot was separated from the white beneath by a deep black border. Tail white, intermixed with a few dark hairs."

A red squirrel with a white tipped tail is noted by McElhinney ('23, p. 77). A similar case is recorded by Bell ('98, p. 78).

A piebald albino is recorded by Klugh ('27, p. 2).

The only other striking deviation from normal coloration that has come to my attention is in a specimen from Fort Resolution, Mackenzie Territory, taken July 22. This is reported by Preble ('08, p. 170) as "very light yellowish-rufous above, sparingly vermiculated with black; the central area of the tail is light rufous, unmarked."

Direction of hair growth. The hair pattern exhibits no peculiarities but is of the type known as normal (Fig. 2). There is a small area of very short hairs on the lower lip, which project perpendicularly from the skin, but otherwise the hairs point caudad, and in general, ventrally. Hairs directed backward offer the least resistance to the air or to solid objects, and progress is thus retarded to the minimum. Any area of reversed hairs would be undesirable in aerial leaps, in rapid passage through dense foliage, or in swimming.

Vibrissae. The red squirrel has well developed vibrissae in areas where such tactile hairs are found in other generalized mammals. These are found on those parts of the body surface which are in most intimate contact with the environment: the head, forearms, and abdomen. The precise rôle which these structures play has not been determined, yet the stimuli received and transmitted by these sensory structures must be of vital importance to a squirrel running and leaping among the swaying branches of trees, for here the eyes alone could not so efficiently serve to determine the exact position of the branch which the squirrel must land upon, nor of the leaves and branches which it must avoid in passage.

In keeping with the grouping of most sense organs at the anterior end of the body, the longest as well as the largest group of vibrissae are found on the upper lip. This is designated the mystacial group (Fig. 3A, MYS). In seven specimens from Long Lake, New York, these tactile hairs are arranged in five

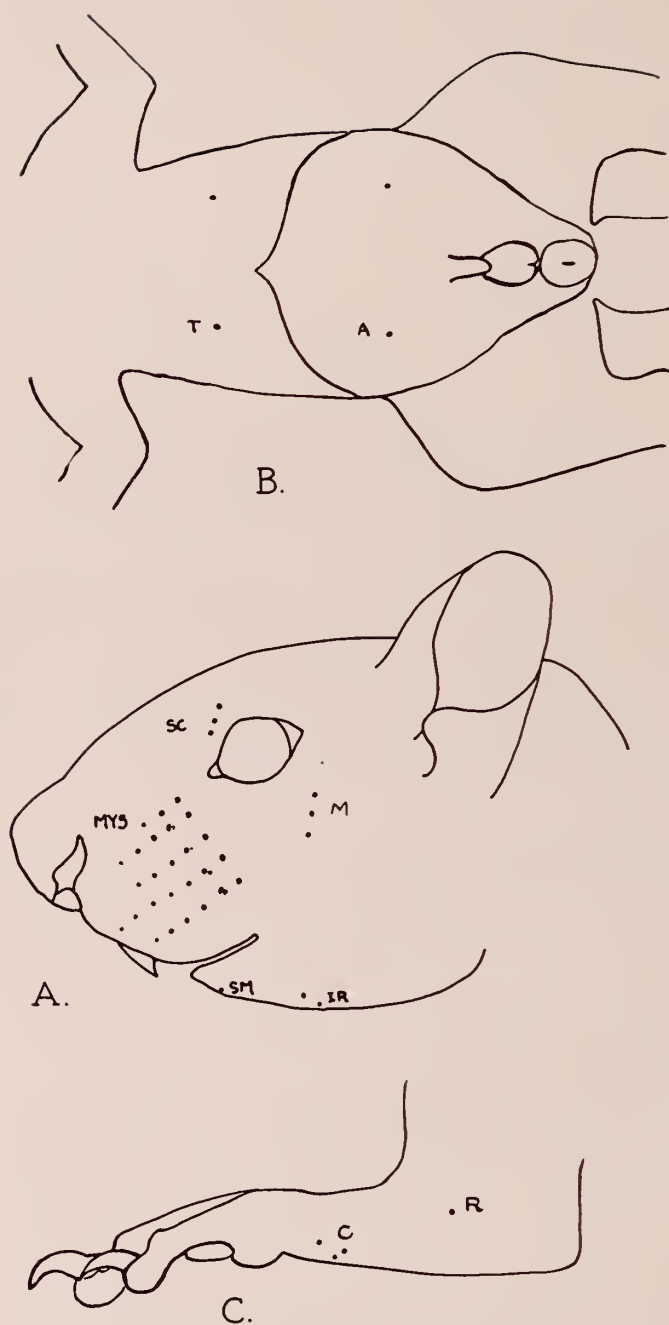


Fig. 3. The distribution of vibrissae on the red squirrel. (*S. h. gymnicus*). A, lateral surface of the head; B, ventral surface of body; C, lateral surface of forearm. Key; A, abdominal; C, carpal; IR, interramal; M, malar; MYS, mystacial; R, radial; SC, superciliary; SM, submental; T, thoracic.

tiers. There is a basal vertical row, each hair of which is the longest in its horizontal tier. From here the vibrissae range anteriorly and are progressively shorter. They grade almost inseparably into ordinary shield hairs, yet position, color, diameter and length usually give a fair criterion for separation. The number found in each of these rows on one of each of the seven specimens is shown in figure 3A. Variation in number was found by Danforth ('25, p. 61) to be less than one per cent in the house mouse. In the red squirrel it seems no greater.

Instead of a single hair arising from the point of intersection of a horizontal and a vertical row, there are not uncommonly two of approximately equal length.

The measurements of the hairs in this group as taken from an adult male (length 295 mm; weight 165 grams; at Long Lake, New York, July 25), were as follows, the lengths in millimeters, reading anteriorly along the horizontal line from the basal vertical row: Tier I (dorsal), 48, 36, 25; tier II, 48, 35, 31, 19.5; tier III, 48, 40, 30, 16, 13; tier IV, 52, 50, 37, 18, 14, 5, 3; tier V, 42, 30, 20, 15, 8, 5.

A second group, the superciliary (Fig. 3A, SC), is found above the eye. Here the hairs are usually three in number. Their lengths on the specimen measured were, from anterior to posterior: 15 mm, 19 mm, and 22 mm. Vibrissae in such a position may aid directly in protecting the eyes.

In the malar group (Fig. 3A, M) likewise the hairs are usually three in number, measuring respectively 28 mm, 28 mm, and 25 mm, the ventral hair being the shortest. This group, leaving the head at its level of greatest width, probably supplements the mystacial group.

In the mid line of the chin, immediately behind the mandibular symphysis, a single tactile hair, the submental (Fig. 3A, SM), frequently occurs. It measured in one case seven millimeters in length.

In the interramal area of the chin, three hairs, two paired and one median, are found. In the adult male measured the paired hairs were 10 mm long, and the single one, 17 mm (Fig. 3A, IR).

On the lateral surface of the carpus occurs a group of hairs, usually three in number (variation in the series of seven specimens ranged from 2-5), which project downwards, one coming into contact with ground or limb before the foot does. These hairs measured respectively 12, 18 and 23 mm in length. They may serve to give notice when its foot is in grasping distance of an object, as the squirrel leaps hurriedly about among the branches.

A single hair occurs (Fig. 3C, R) on the lateral surface of the forearm, over the proximal head of the radius. This measured 23 mm in length.

On the ventral surface of the body are two pairs of hairs, one thoracic and one abdominal. The thoracic pair (Fig. 3B, T) measured 21 mm and the abdominal pair (Fig. 3B, A) 19 mm.

The vibrissae are practically always black, though I have found the interramal and submental vibrissae a pure white when the other vibrissae on the individual were black.

While the tactile hairs of the squirrels are well developed compared with those of many other land mammals, yet in their groupings, their arrangements and numbers, they are quite primitive or at least generalized, for other rodents, many

marsupials and carnivores, as well as more specialized groups of mammals, present exactly the same groupings and frequently the same numbers of vibrissae.

ANATOMICAL SPECIALIZATION

The head. The head of the red squirrel is short and broad and characterized by a curved dorsal outline. The cranial portion is expanded to accommodate a brain probably superior to that of ground dwelling rodents. The large black eyes lie midway between the moderately large ears and the small nasal pad. Bifocal vision, seemingly essential to rapid and accurate judging of distances before a leap, has apparently not been developed, for the eyes are strictly lateral. They are protected by a sharp supraorbital ridge and postorbital process of the frontal bone. The dorsal lip is cleft to allow free play of the incisors. The lower incisors by means of muscles inserting on the mandible may be held with tips in close proximity for gnawing hard objects, or with tips apart for seizing softer objects. No cheek pouches occur. The short nasal chamber and simple ethmoturbinals suggest a relatively poorly developed sense of smell, as might be expected in an arboreal creature.

The dental formula of the red squirrel is, I, $\frac{1}{1}$; C, $\frac{0}{0}$; Pm, $\frac{1}{1}$; and M, $\frac{3}{3}$.

The incisors are scalpriform, growing from persistent pulps. The enamel being confined to a heavy band on the anterior surface, there is a more rapid wearing away of the dentine behind, so that the teeth are automatically sharpened by gnawing. The cheek teeth are brachydont with an evident tritubercular pattern. The diastema between the incisors and premolars gives free play to the gnawing motions of the incisors and allows the squirrel to carry fairly large objects in its mouth.

The masseter muscles are relatively tremendously developed, so that the squirrel can use effectively its sharp incisors on such hard shelled nuts as those of the hickory. In harmony with this the malar arch is broad, *Musculus masseter lateralis* passes obliquely upward to the superior border of the rostrum, to the exclusion of *M. masseter medialis*. The inferior infraorbital foramen transmits the nerve only. It is protected from muscular action by the presence near its lower border of an outgrowth for the attachment of *M. masseter lateralis superficialis*. In connection with the development of *M. temporalis* there is a slender decurved postorbital process, though there is but a vestige of a corresponding process on the zygoma.

Tail. Although short and narrow for a tree squirrel, the tail is nevertheless one of the animal's most essential assets. The caudal vertebrae are about two-thirds as long as the head and body, while the tail to the end of the hairs is about one-seventh shorter than head and body. The tail though primarily distichous would be considered terete in comparison with that of the flying squirrels. It is not prehensile.

The tail serves to aid the squirrel in balancing while climbing or leaping, and to lessen the force of impact at the end of a fall by increasing the surface area; it serves as a wrapper when the animal rests in cold weather, and is an adjunct to the expression of emotion. Its loss presents therefore a serious handicap. Of a

total of 42 specimens taken in the Harvard Forest and in the Adirondacks, four had a portion of the tail missing. All the injured specimens were adults. In the remaining 38 there were 15 uninjured adults and 23 uninjured young. Seton ('09, p. 317) states that half the squirrels he took about Kenora [Manitoba], in 1886, had some tail injury.

The cause of these injuries is not known. The skin of the tail slips off easily, and with this casing gone the exposed vertebral series would soon become dry and break off. It may be significant that three of my four injured specimens were females. Possibly the male in pursuing his mate occasionally seizes the tail with his teeth with this disastrous result. One of the injuries noted was recent, fresh scar tissue being clearly marked (July 16, ad. female). The unusual instance of a trout stripping the tail from a red squirrel is recorded by Seton ('09, pp. 317-318). Fighting among adults and young, the attacks of enemies, disease, or freezing might each be responsible for loss of the tail.

The tails of my four injured specimens were reduced to lengths of 103, 103, 101, and 89 millimeters, respectively, compared with an average adult tail length of over 116 millimeters for specimens from either locality.

A bob-tailed squirrel is not of necessity doomed to an early death, as is attested by the presence of so many injuries of long standing among the squirrel population. Neither is such a squirrel incapable of normal behavior in the tree tops. I have watched a pair of red squirrels feeding near the top of a tall elm, and though one of these had lost fully half of its tail, it seemed at no disadvantage in balancing on the smallest twigs. A heavy wind was striking the top of this tree, and the branches, on the tips of which this chickaree fed, swung in arcs probably five feet in diameter. Occasionally the squirrel would stop feeding while some unusually violent swing of its perch expended its force, but on the whole the injured one was as agile and fearless as any red squirrel I have ever watched. This squirrel's companion, though possessing a normal tail, did not venture out to the tips to feed, or take the risks accepted by the less well equipped individual.

That squirrels with injured tails soon disappear is held by Seton ('09, pp. 317-318), though he gives but one instance (insufficiently detailed) to support his statement.

Fore limbs and hands. The fore limbs of the red squirrel are of moderate length and terminate in slender fingered unguiculate hands. The radius and ulna are free and permit rotary motion of the forearm. The thumb is vestigial, in correlation with hanging, as in many other arboreal animals. A pad which covers the site of the reduced pollex is opposable to the tightly bound fingers, and allows the squirrel to use its hands effectively. Palmar and sub-terminal toe pads add to its grasping power. Objects of all manageable sizes are handled rapidly, and so dexterously that but rarely is an object let fall. The squirrel may reach out and with a single paw pull off a bud, a rose hip (Klugh, '27, p. 13) or a leaf (Klugh, '18, p. 11), and in doing so holds the fingers against the palm. The claws are thin, curved and sharply pointed. They are admirably adapted for climbing even on a relatively smooth surface, for picking up and holding objects, and for fur combing. In digging, the claws are suitable only in such soft media as thoroughly rotted wood, snow, and the loosest of soils.

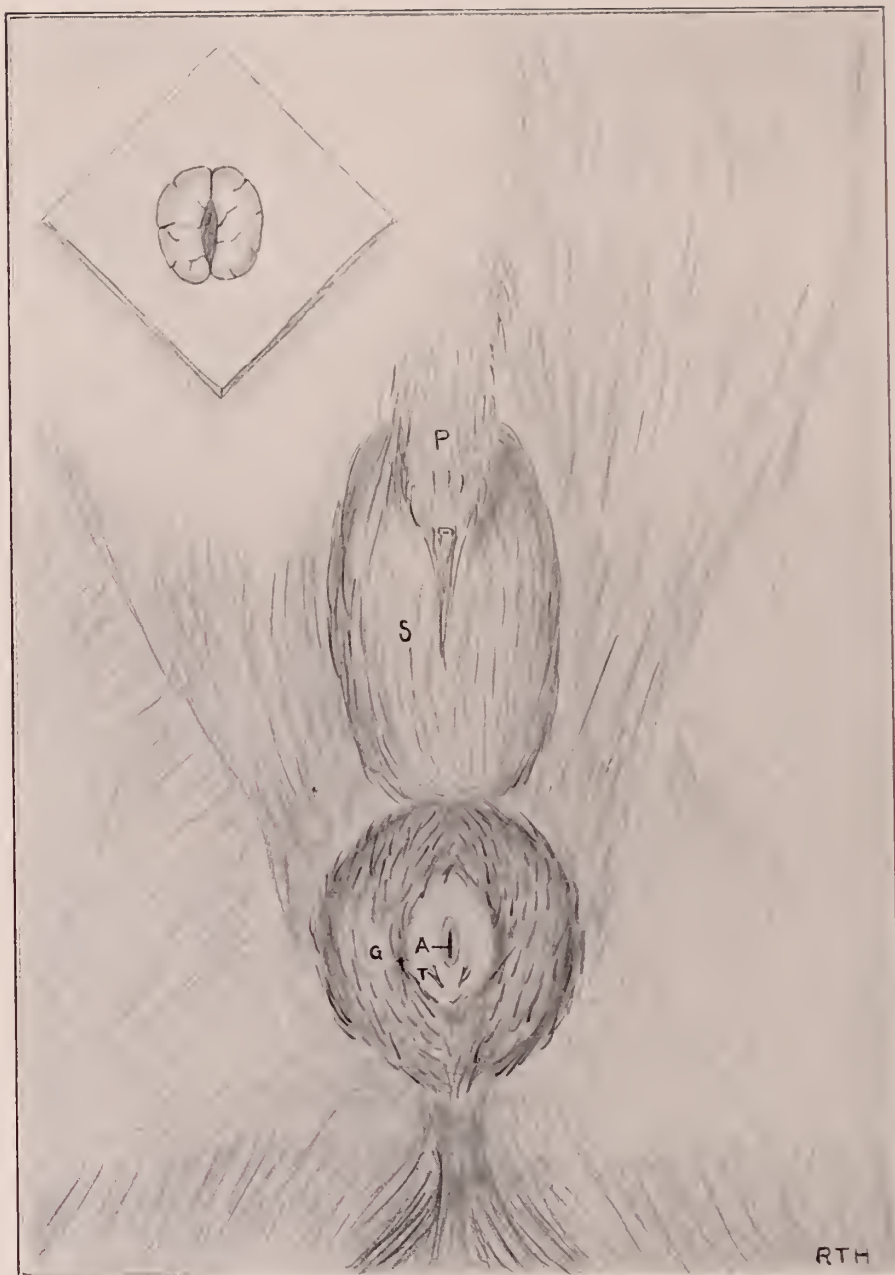


Fig. 4. Inguinal region of an adult male red squirrel (*S. h. gymnicus*), showing glandular perianal enlargement. Insert: The anal glands viewed from the deep surface of the skin. Key: A, anus; G, ridge due to bulge of anal gland; P, prepuce; S, scrotum; T, tuft of hairs at glandular pore.

Perfect clavicles and strong pectoral muscles are correlated with the squirrel's arboreal habits.

Hind limbs and feet. The hind limbs of the red squirrel are considerably larger than the fore limbs, in correlation with its leaping powers. The primitively pentadactylous foot, longer and more slender than the hand, is less versatile in its motions. Klugh ('27, p. 23) states: "In maintaining this [hanging] position on the under side of limbs they rely chiefly on their hind legs, and there is a decided outward bend in these legs at the tarsal joint which evidently enables the claws to catch the crevices of the bark more effectively."

Digestive tract. The stomach is thin-walled, with muscular tissue poorly developed. There is no external evidence of a pyloric valve. The highly comminuted character of the squirrel's swallowed food accounts, doubtless, for the simplicity of the stomach.

The small intestine is a uniform unconvoluted thin-walled tube. In a small female it measured 1255 mm in length, and 4 mm in width when collapsed.

The caecum is simple, vermiform, and but slightly convoluted. It measured 60 mm in the female specimen just mentioned.

The narrow colon-rectum measured 285 mm in length.

Anal glands. In both male and female red squirrels occurs a pair of scent glands disposed in a circum-anal position (Fig. 4). The two pores of these glands appear on the crest of nearly naked ridges (G) (caused by the presence of the glands) on either side of the anus (A). The position of these pores is marked by small tufts of hairs (T).

The gland body (insert, upper left corner Fig. 4) lies in a subcutaneous position, superficial to *Musculus sphincter ani*. The gland itself is, however, covered on its deep surface by a thin muscle which is in direct continuation with the skin muscle. Here it forms a sort of post-pelvic diaphragm. The gland bodies are flattened, measuring from 10 mm to 12 mm in cranio-caudal and transverse diameters, with a thickness of 8 mm. Because these glands are so large they produce a distinct swelling on the surface of the body and form a scrotum-like sac about the anus.

Viewed from the deep surface the glands are seen to be heavily convoluted, resembling a mammalian cerebrum, and are a deep corn yellow in color.

The gland possesses a distinct dry musty odor, perceptible on living squirrels, yet to my nose identical in both sexes. The fluid is clear, and light yellow in color. There is no large reservoir for its storage.

The pores are so placed that some of the secretion must be left on all voided feces and on such resting places as branches of trees.

Mammae. The mammae are distributed as follows; 2 thoracic, 0 abdominal, and 2 inguinal.

Size and Weight. The series of specimens (*S.h. gymnicus*) from which my averages are taken were secured in the Adirondack region, between July 5 and September 10.

The average total length of 14 adult squirrels was 299 mm, with extremes at 281 mm (several males and females) and 336 mm (a female). The tail length of 14 specimens averaged 122 (113-140) mm, the hind foot of 17 averaged 47 (41-49) mm, while the ear of the same series averaged 17.1 (11-21) mm from crown of skull to tip of ear.

The mean weight of 14 adult specimens was 170 grams. The lightest of these, considered adult, weighed 135 grams; the heaviest, a female with large embryos, weighed 262 grams. There was no appreciable weight difference between males and non-pregnant females, neither was there any distinct increase in weight during this season. In size, this series ranges closer to *S.h. hudsonicus* than to *S.h. gymnicus*, though the pelage of Adirondack squirrels is nearer to that of *S.h. gymnicus*.

LOCOMOTION

Arboreal adaptation. Though the red squirrel spends more time on the ground than do its near relatives of North America, the creature is primarily arboreal and for such a life it is admirably adapted. A lithe yet muscular body; a tail with hairs spread for guidance in leaping and for the purposes of a parachute in falling; sharp, curved claws on all feet; and long stout vibrissae developed where they are most needed are his principal visible qualifications for a life in the trees.

The agility and the speed displayed by the chickarees in ascending and descending tree trunks and in passing over the limbs are almost incredible. The squirrels seem always sure of their footing and it is but rarely that they fall. I have seen an excited chickaree "hitching" head down along the vertical trunk of a dead tree when evidently the bark under its feet gave way. The squirrel managed to spring from this moving foothold to the trunk and thus regain its safety, though not its composure.

A red squirrel constructing a nest fifty feet from the ground in a white pine was seen to make the trip from the nest to a point on the ground ten feet from the base of the tree, 12 times in 12 minutes. The quickest round trip was made in 35 seconds. On all but two descents of lightning-like speed the squirrel checked itself on the stub of a limb and rested for a few seconds with tail straight behind, twitching lightly. On the return trip the nest builder would stop about five feet up the trunk, and, clinging with its rear feet only to a slight protuberance in the rough bark, adjust with its hands the nest material which it carried in its mouth. That the squirrel did not fall backwards seemed extraordinary. On the down trip the squirrel followed almost exactly the same route each time, utilizing the trunk and the laterals. On the trip to the nest varying routes were used, and though the squirrel proceeded more slowly than in the descent, its progress was never interrupted except for the momentary stop to adjust its load, as mentioned before.

The progress up a tree is essentially a gallop, the fore and hind feet being used alternately in pairs. In descending, the squirrel moves head downward, and ordinarily uses the feet individually. If excited over some unfamiliar sight it may move down in a series of jerks, which appear to be due to the release simultaneously of the claws of all feet for a fraction of a second and the quick seizure of a new hold.

The chickaree is able to travel on the underside of branches although, except in feeding or in frolicking with another squirrel, it probably never does so.

Leaping. A century old statement (Goldsmith, '35, p. 190) credits an undesigned species of squirrel (probably *S. vulgaris* of Europe) with this very remarkable leap: "Its usual way of moving is by bounds; these it takes from one tree to another at forty feet distance."

A jump of eight feet with a drop of two, is recorded by Klugh ('27, p. 10) who writes that one squirrel made this leap several times each day, though the return leap was never attempted. This same writer records a remarkable leap of five feet with a rise of three feet. I have observed a leap of six feet with a drop of three feet, where the take-off was from a moving branch.

In a measured jump of thirty-four inches between two upright posts a squirrel took off in a head-down position and landed with its head pointing upward. In a sixty-four inch jump from a horizontal rail to a vertical tree trunk this squirrel took off in a horizontal plane and completed the jump head upward and body parallel to the tree trunk.

In leaping, the legs are extended, the body flattened, and the tail held stiff and straight behind, unless the leap is poorly made because of an insecure starting point. In the latter case the squirrel makes desperate efforts by movements of its tail and legs to maintain its direction while in the air, according to Klugh ('27, p. 11). Burroughs ('01, p. 5) states that the tail is arched and vibrates rapidly when the squirrel is leaping, though he apparently made his observations on squirrels leaping from insecure bases.

Long forced leaps from some high point to the ground are made by squirrels when no other way of escape is possible. Burroughs ('01, p. 3) mentions the instance of a red squirrel which took refuge in a tall hickory. Being closely pressed the squirrel leaped boldly into the air, "spread himself out upon it, and with a quick, tremulous motion of his tail and legs, descended quite slowly and landed upon the ground thirty feet below me, apparently none the worse for the leap, for he ran with great speed and eluding the dog took refuge in another tree."

A Mexican black squirrel is credited with two remarkable leaps by a traveler whom Burroughs ('01, pp. 3-4) quotes anonymously. The squirrel, "nearly as large as a cat," had been caught by two boys. Escaping them, to avoid recapture it leapt sixty feet from the top of a pine to the roof of a house, without injury. The squirrel, suspected of being bewitched, was recaptured and taken in a pillow slip to the edge of a six hundred foot precipice. The slip was opened and the squirrel allowed its choice of captivity or a leap into space. The squirrel seeing no other means of escape "took a flying leap into space, and fluttered rather than fell into the abyss below. His legs began to work like those of a swimming poodle dog, but quicker and quicker, while his tail, slightly elevated, spread out like a feather fan . . . [he] landed on a ledge of limestone where we could see him plainly squat on his hind legs and smooth his ruffled fur, after which he made for the creek . . ." The story is probably exaggerated though not altogether incredible.

A gray squirrel was frightened from its nest in the top of a thirty-five foot Douglas fir, by a friend of the writer. It leaped from a branch at the level of the nest out into the air and landed on the snow below without evidencing any injury.

Falling. The chickaree often jumps in a great hurry from a springy or swaying branch and in such a case may miss its intended landing place. In most cases which I have observed the squirrel has seized with its fore paws the tips of some branch which it was passing, and has thus been spared a more serious fall. Though a squirrel does not often fall completely to the ground, almost every one who has spent many hours in the forests watching squirrels has seen such a fall.

It has been my fortune to observe one such accident. A squirrel, after scolding my companion and me for a minute, climbed to the top of the spruce in which it was found and jumped into a small sugar maple. From this tree it hurriedly attempted a leap of little more than a foot between the small twigs of the maple and those of another tree. Its foothold had been treacherous, however, and down the squirrel came, directly above my head. With legs outspread (I did not see the position of its tail) and belly towards the earth, it fell the thirty feet to the ground, not perpendicularly but at an angle that carried it about five feet away from me. Before I could cover the squirrel with my hat it scampered to safety in the nearest tree.

Recording the twenty foot fall of a young chickaree, Grinnell and Storer ('24, p. 205) state that a falling squirrel distributes the shock of impact and saves itself from serious injury by spreading out all feet widely.

Two falls of about thirty feet on the part of a squirrel which was being driven from the territory of another squirrel are recorded by Klugh ('27, p. 11). In both cases the squirrel landed poorly, once on its side, so severely that it was some minutes before it recovered sufficiently to crawl to the tree and climb up. The other time the squirrel landed on its back on a sheet of ice and appeared to be badly shaken. Klugh ('27, p. 11) also writes of having at one time found a young squirrel which had apparently fallen from a high limb of an elm to a cement sidewalk. The squirrel was squatting on the walk, repeatedly rubbing its head with its fore paws, and looking very much dazed.

A fall of over one hundred feet is described by Spreadborough ('19, p. 61) who writes: "On one occasion when in the woods I saw two of them fighting in the top of a tall tree. They clenched and rolled up like a ball; the consequence being that they both fell from the branch. After falling some fifteen or twenty feet they both let go of each other and one managed to seize a branch; the other fell about a hundred feet and was unhurt, for no sooner did he hit the ground than he made for a tree again and climbed to the top to finish the fight."

The longest fall I have found on record (Shufeldt, '20, p. 41) was that of a large red squirrel at the National Zoological Park which fell from the top of a one-hundred-and forty-foot shagbark hickory when the bark broke beneath the animal's weight. The squirrel, which fell belly down, tail outstretched, and feet clutching the air, was not stunned, for in five seconds it scampered away again.

Terrestrial Locomotion. The squirrels though born in the trees spend many hours of their lives on and under the ground in search of food and water, in storage activities, and in traveling about. Squirrels do not seem so self-assured on the ground as in the trees, however, and travel more frequently from branch to branch or, along those clear and comparatively safe highways, the stone walls of New England and the rail fences of the Middle West.

It has been my observation that when a squirrel is frightened it will usually take to the trees and when seeking escape will stay in the trees only so long as it feels the proximity of danger. It then, if desiring to travel farther, frequently descends to the ground where it can make better speed and moves directly away. Its behavior in this respect appears to vary with the distance to the area which the squirrel considers its home.

In traveling over the surface of the ground the squirrel commonly moves in a line that approaches the bases of trees. I have, however, seen a squirrel travel without exceptional haste, yet without foraging, for two hundred yards through a forest before ascending a tree. In late summer it is a common sight to see one squirrel pursuing another for long distances on the ground.

Large open areas are avoided because of the numerous enemies in the air and in the grass, yet red squirrels occur in isolated groups of trees which they must have reached by hazarding such an exposure to attack.

When the red squirrel is foraging on the ground its feet are moved independently in a walk; otherwise its gait is a gallop. The hind feet are held further apart than the fore feet, and when progress is rapid they are planted considerably ahead of the fore feet. The amount of overstep is in direct ratio with the length of the jump. If the gait is slow the imprints of the hind feet show behind those of the fore feet. The longest jump that a squirrel can make on level snow is about five feet, according to Seton ('09, p. 318) who has measured many leaps on trails left by squirrels pursued by men and dogs.

The red squirrel digs pits, tunnels, and hollows in the earth and in the snow. In the earth it caches food, builds nests, and probably spends some time in resting and playing. I have not seen squirrels engaged in building the longer tunnels, but the shallow pits are made by the squirrel firmly bracing its hind feet and digging in a dog-like fashion with its fore feet. Such holes are filled in by tamping with the fore feet.

Swimming. Numerous published accounts of the swimming of red squirrels show clearly that these animals will take to the water voluntarily and are capable of swimming great distances. In some cases the swimming appears to be due to a desire of an individual squirrel to reach the opposite side of a body of water, and in other cases there is evidence of some group movements that might be called migratory. Red squirrels, however, seldom work together and it is probable that when many of these creatures swim a body of water in a certain season it is because the same external or internal factors are acting on each individual, rather than that there is a concerted action on the part of a colony.

My own observations, based on swimming squirrels which were dropped from a boat, show that the squirrel swims with the greater part of its head, the top of its shoulders and the back of the tail showing above water (Fig. 6). It swims with the tail stretched straight and flat on the surface of the water. Such a position of a swimming squirrel has also been described by Cram ('99, pp. 222-223), though in this case, too, the squirrel had fallen into the water accidentally. A red squirrel, apparently migrating and which presumably had entered the water voluntarily, is described by Cole ('22, p. 53) as follows: "The individual we saw swam calmly and evenly with the head well up, shoulders nearly

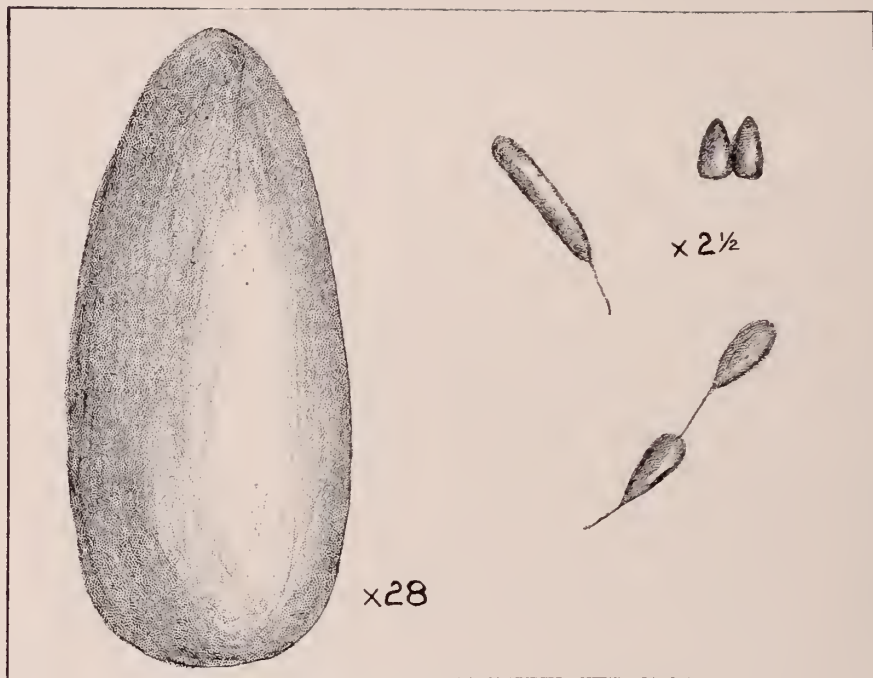


Fig. 5. Feces of a red squirrel (*S. h. gymnicus*).

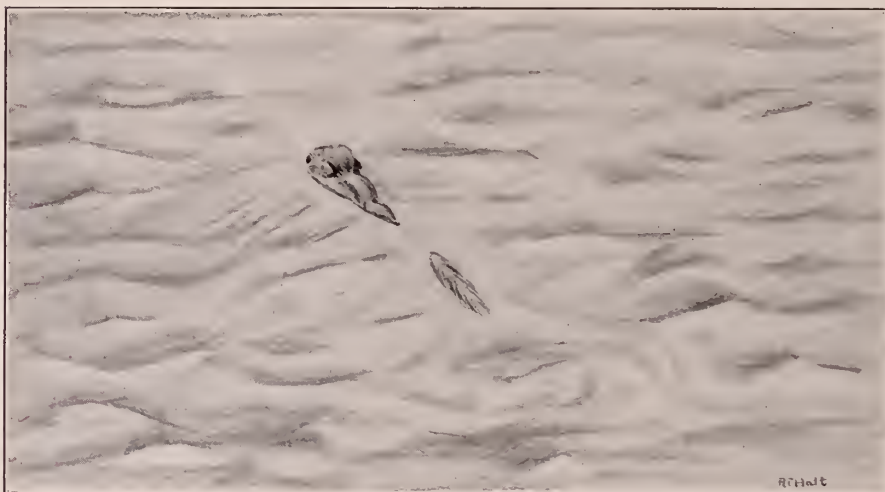


Fig. 6. Swimming red squirrel. Drawn from photographs and field notes.

submerged, but rump and tail high." Merriam ('84, p. 216), too, relates having seen a squirrel swimming a stream, with much of the head, back and tail out of water. But a quite different picture is given by Merriam (op. cit., p. 217, quoting W. C. Watson's History of Essex County), when, in describing migrating squirrels, he writes of them as moving with "their heads above water and their bushy tails erect and expanded, and apparently spread to the breeze."

The hind feet are kicked out in vigorous steady alternation in a vertical plane. I have been unable to see whether or not the fore feet also are used. The tail does not serve as a rudder, but the position of the head and body, and, probably, the movements of the feet serve to guide the animal.

Squirrels are strong swimmers as attested by the long distances they are known to swim, as well as by the following incidents.

Klugh ('27, p. 13), quoting a letter from Allan Brooks, writes:

"I was walking along a big mining ditch about nine feet wide in which the water was running swiftly when I saw a curious animal coming down the bank on the other side. Presently I saw it was a red squirrel staggering under the load of a two-thirds grown young one wrapped round its neck just back of the head. It came straight for the water and swam across, landing in front of me, and climbed the bank to my feet. Here it first caught sight of me, threw off the young one, jumped into the water, swam over, ran up the bank and into the woods. The young one ran up to me, stopped on my chest just below my chin for a second or two, then ran down into the water, swam across, ran up the bank and off into the woods after its mother.'"

Jackson ('08, p. 16) writes: "I have frequently seen them swim through rapids which would baffle many aquatic animals. On one occasion I saw a red squirrel in North Pelican Lake swimming from one point of land to another fully ninety rods distant and so skillful was he in his efforts that at a distance I mistook him for a mink."

A red squirrel swimming the West Branch of the Penobscot River, Maine, where it was about fifty yards wide and quite swift, is described by Pope ('24, p. 134) who adds that it swam to shore with great difficulty. Another was seen at the head of Attean Lake, Maine, where the lake was one-quarter to one-third of a mile wide. The squirrel was about half way across and at the rate it was swimming should have taken fifteen to twenty minutes to make the crossing, if it had not been interrupted.

Red squirrels were frequently seen in the middle of Lake Champlain where it is seven miles broad, during the autumnal migration of 1851 (Merriam, '84, p. 277, quoting W. C. Watson's History of Essex County).

Red squirrels have been seen swimming Long Lake in the Adirondacks where it is a mile and a half broad, by Wallace Emerson of Long Lake.

That the squirrel is able to dive in order to avoid a threatened blow is attested by DeKay ('42, p. 62,) and by Audubon and Bachman ('49, p. 130) who add that its dives are short, ineffectual plunges of a foot or two at a time, which it takes when stoned by boys.

An early account found in Goldsmith's Natural History ('35, p. 190) of the swimming habits of *Sciurus vulgaris* during its migrations in Lapland can scarcely be credited in full though it is of sufficient interest to quote:

"Upon approaching the banks, and perceiving the breadth of the water, they return as if by common consent into the neighboring forest, each in quest of a piece of bark, which answers all the purposes of boats for wafting them over. When the whole company are fitted in this manner, they boldly commit their little fleet to the waves; every squirrel sitting on its own piece of bark, and fanning the air with its tail, to drive the vessel to its desired port. In this orderly manner they set forward and often cross lakes several miles broad. But it too often happens that the poor mariners are not aware of the dangers of their navigation; for although at the edge of the water it is generally calm, in the midst it is always more turbulent. There the slightest additional gust of wind oversets the little sailor and his vessel together. The whole navy that but a few minutes before rode proudly and securely along is now overturned, and a shipwreck of two or three thousand sail ensues."

It might easily be imagined that a swimming squirrel would climb up on some floating driftwood to rest, and the habit of our red squirrel of excitedly jerking its tail at the approach of some intruder might well have given rise to certain parts of this fable. Since many individuals of a migrating horde have doubtless been found to have been drowned in their attempt to cross a body of water, and their bodies washed ashore, the narrator may have thought he had sufficient evidence to complete his story of a wrecked flotilla.

A swimming red squirrel when approached in a boat seems to lose its customary fear of man and, if given a chance, climbs up to rest, or to run the length of the boat and again enter the water. The squirrels which I have put into the water from a boat always attempted to climb back as rapidly as possible. Sometimes they succeeded by climbing the bow (Fig. 8) or an oar, and once by climbing a trailing rope. Each time after they had re-entered the boat they dodged any further attempt to dislodge them, and sat usually at the bow or stern, shivering and dripping until we again tried to put them in the water. They would allow themselves to be touched, would run along the gunwales, or over our knees, but stubbornly refused to leave the boat. Once when the boat was moved rapidly away from a swimming squirrel the animal circled once for orientation and then struck out directly for the nearest shore point, some fifty yards away.

A squirrel swimming in the middle of a quarter-mile-wide lake was taken into a canoe by Pope ('24, p. 134). The squirrel stayed, chilled and tired, on Mr. Pope's knee until shore was reached. Another squirrel swimming a river entered a canoe by way of a paddle, ran the length of the craft, and again took to the water. Merriam ('84, p. 216) records the case of a red squirrel which entered his boat, ran to the bow, jumped off and swam in the same direction as before, until the boat caught up, when it climbed into it again. The whole performance was repeated several times before shore was reached.

Squirrels swimming Long Lake, New York, Ranger Isaac Robinson informs me, will enter a boat and remain in it as long as the vessel continues in the direction in which they were originally proceeding.

On emergence from the water the squirrel sometimes presents anything but a happy sight, for his fur may be thoroughly soaked. This was the condition of the two individuals which I have seen land. The squirrel shown landing in figures 9 and 10 climbed up on a little shelf at the base of a vertical cliff, from which



Fig. 7. Red squirrel (*S. h. richardsoni*) arrested in its descent of a tree. Yellowstone Park. Photograph by J. M. Johnson.



Fig. 8. Red squirrel on bow of boat. Lake Champlain, N. Y. September 8, 1926.



Fig. 9. Red squirrel shaking water from its fur immediately after landing. Valcour Island, N. Y. September 2, 1926.



Fig. 10. Red squirrel drying in the sun. Valcour Island. September 2, 1926.

he could not escape without again entering the water. He allowed me to sit beside him and to touch his head. Although he shivered, his fur dried quickly in the warm sun. When his composure was somewhat regained he rubbed his belly over the warm dry rocks. Later he was given his freedom by means of a board which allowed him to reach a portion of the cliff that he was able to climb. A squirrel which had fallen into the water is described by Cram ('99, p. 223) who states that, on emergence, though the squirrel shook himself the fur did not rid itself of water and he really looked worse than ever.

A strikingly different account is given by W. C. Watson, whom Merriam ('84, p. 217) quotes:

"Reaching land they stopped for a moment and relieving their active and vigorous little bodies from water by an energetic shake or two they bounded into the woods as light and free as if they had made no extraordinary effort."

It is in this same account that they are described as swimming with their tails erect and spread to the breeze.

RANGE AND DISTRIBUTION

Origin and Spread. The red squirrel is undoubtedly of Mexican or Central American origin, according to Allen ('77, p. 670). It is suggested by Adams ('09, p. 402) that the species apparently crossed the Rocky Mountains from the East, perhaps near the Canadian Boundary. Further, he writes (op. cit., pp. 401-402):

"This extensive geographic range in the Canadian forested region and in Alaska is of special interest. The far northern range of this form and its great abundance suggest that it is well adapted to the region it inhabits. It is evidently a glacial or post-glacial migrant into most of its present northern range, as the entire area (excepting part of Alaska) lies within the region glaciated by the Wisconsin ice sheet. It seems probable, therefore, that at the time of the maximum extension of this sheet this squirrel frequented largely the coniferous forests at its southern border—east of the Rocky Mountains—and as this sheet retreated northward it spread with the forests into the area now occupied. It also seems likely that their main headquarters were in the region south of the Great Lakes and eastward, because the probable aridity of the Great Plains in glacial times would be unfavorable to extensive forest growth. The glacial and post-glacial migrations of the Red Squirrels as far as they can be inferred may explain some of the peculiarities of their present range. . . . It also seems probable that the geographic isolation and the peculiarities of the Black Hills Red Squirrel (*S. hudsonicus dakotensis* Allen) may be explained, in part, if it be considered a glacial relict which has become isolated by the change of climate attending the decline of the Ice Age."

There is evidence of a southward extension of range through the middle west in recent times, due possibly as Kirtland ('38, p. 176) suggested, to the extension of cultivation. Kennicott ('57, pp. 68-69) writes: "Like the red fox and some other animals this squirrel appears in some instances to follow the settlements of the white man. In parts of Northern Illinois where it was not seen formerly it is now occasionally found, and is increasing in numbers. Dr. Kirtland speaks of it

as having scarcely made its appearance about the beginning of the present century, on the Western Reserve, in Ohio, where it is now exceedingly abundant. It may be, however, that this appearance of the red squirrels in these localities is the result of the destruction of certain enemies. It is very certain that they were abundant further to the west and north, before any settlements were made there."

In Indiana the red squirrel is extending its range southward, according to Evermann and Clark ('11, p. 6), who give a few records in support of this contention. More recently Walker ('23, pp. 127-128) writes that prior to August, 1909, the nearest red squirrels were eight miles northeast of his home near Sheridan, Central Indiana, but that by March, 1921, the species had reached the vicinity of his home. They seemed to be on the increase and to be driving out the fox squirrels.

Factors of Distribution. The red squirrel is probably limited in its distribution to the North only by the failure of food supply. In the East and the West the sea alone limits the spread of its population. In the Southeast the barriers may be climatic, or those concerned with food. To the Southwest the deserts and plains are the natural barriers, except in the mountains where the ancient stock of *Tamiasciurus* has differentiated as *S. fremonti* and *S. douglasii*.

Locally, water even of considerable expanse is not an effective barrier, for if the squirrel does not cross over the ice in the winter, it may swim at another time. Red squirrels occur on Valcour Island, Lake Champlain, which is one mile from the mainland. Jackson ('20, p. 62) records them on the Apostle Island of Lake Superior, where the greatest stretch of open water to traverse is one and a half miles. I have ('24, p. 399) recorded it from Fox Island, Lake Michigan, seventeen miles from the shore. Adams ('09, p. 399) records them on Isle Royale, Lake Superior, which lies about twenty-five miles from the north shore. They are supposed by Adams (l. c., p. 395) to have gained access to this island by means of driftwood and lake currents. Couper ('77, p. 300) states that they do not occur on Anticosti. Extreme cold in itself appears to be no barrier to the red squirrel, for Preble ('02, p. 45) writes that it is abundant and generally distributed to within a few miles of York Factory, where the trees dwindle to an insignificant size, affording no congenial home to the species. Murie ('27, p. 37) writes that they probably occur to the limit of forest growth in the Endicott Mountains of Alaska, where temperatures of seventy degrees below zero Fahrenheit sometimes occur. I have myself seen *S. fremonti* at timberline on Pike's Peak, Colorado, an altitude of 11,500 feet.

The cause of dispersal of the squirrel is, possibly, as with other species, principally over-population, though abnormal causes such as floods and fires occasionally initiate a movement. Extension of habitats at the periphery of the range makes possible an extension of the squirrel population.

In local distribution, habitat preference depends much on food supply, but the suitability of nest sites must play the major role. The red squirrel at first retreats before the advance of cities, but later may return. In South Bend, Indiana, the squirrels, according to Hahn ('09, p. 469), have taken up residence in the Catalpa trees.



Fig. 11. Adirondack forests, typical of the red squirrel's range in this section. View north from Blue Mountain. July 20, 1926.



Fig. 12. Red spruce and young hardwood stand. Hamilton Mountain, in the Adirondacks. Red squirrels are common in this habitat. June 19, 1926.

Migration. There are several accounts of the migration of red squirrels which tend to establish migration as a normal movement of part of the species in certain areas. It is probable that such migrations occur only in times of maximum population and of food shortage, for certainly there are no regular seasonal movements of all the red squirrels. The migrations appear to be overflow movements due to an urge of hunger.

Red squirrels are commonly seen swimming Long Lake, New York, I was told by Ranger Isaac Robinson. Though he could not recall specific instances, it was his impression that he had seen them swimming the lake most frequently in the autumn; and that they were most commonly seen swimming in the years of poor beechnut crops. They have been seen crossing the lake in both directions. Wallace Emmerson, a guide of Long Lake, also reports this fact.

In his *Mammals of the Adirondacks*, Merriam ('84, p. 217) writes:

"I am informed by Dr. A. K. Fisher that at the southern end of Lake George, in early autumn, it is sometimes an every-day occurrence to see Red Squirrels swimming across the lake, from west to east—never in the opposite direction. The chestnut grows abundantly on the eastern side of the lake, but it is comparatively scarce on the western, and these extensive migrations always take place in years when the yield of chestnuts is large. A few squirrels are occasionally seen crossing the lake when the nut crop is only moderate. In September, 1882, Mrs. Fisher was angling between Diamond Island and the west shore when a Red Squirrel swam to the boat and was lifted by the tail. After resting a few minutes it ran out on an oar, jumped into the water and swam to the island (which is half a mile from the west shore), and thence, doubtless, to the chestnut groves on the eastern side of the lake."

Further, quoting W. C. Watson's *History of Essex County*, Merriam (*ibid.*) writes:

"The autumn of 1851 afforded one of these periodical invasions of Essex County. It is well authenticated that the red squirrel was constantly seen in the widest parts of the lake [L. Champlain] far out from land, swimming towards the shore as if familiar with the service."

Merriam ('84, p. 217) quotes James Higby as saying that in June, 1877, he saw as many as fifty red squirrels crossing Big Moose Lake, all headed north.

At White Sand Lake, Wisconsin, Cole ('22, p. 53) saw a red squirrel swim to shore after having crossed the lake, and he was told by a boatman that squirrels had been crossing the lake for several days.

"In the winter of 1918 large numbers of red squirrels [*S. douglasii albolimbatus*]," write Grinnell and Storer ('24, p. 203), "moved down into the Valley [Yosemite] from the surrounding high country, and some of them were still present at the beginning of summer in 1919."

Similar accounts have appeared of the migration of *Sciurus carolinensis* and *S. vulgaris*.

RED SQUIRREL HABITATS

With the progressive change in the topography and the flora of any region there follows a corresponding change in the mammal fauna. As Adams ('09, p. 392) has pointed out, the red squirrel advances as the forest invades the open swamp, and on bare surfaces where scattered jack pines obtain a foothold, the red squirrel may follow and find food. The prairie is invaded by yellow pine, into which the squirrels may come, though in small numbers. Eventually follows a forest of hardwoods and with it a year round food supply on which the red squirrels may thrive and consequently multiply.

Though the chickaree in some parts of its range is divorced from its association with the conifers, it is in the vast areas of spruce and the pines deficient in pitch that the animal flourishes without competition from the fox squirrel and the gray squirrel.

In the southern and eastern parts of its range where habitats are more varied yet less well marked, the chickaree finds a congenial abode over a greater territory in the aggregate than in the West and the North. The animal must have an abundant food supply available the entire year within its small home area. In consequence the habitat must either offer a great abundance of one type of food, as in the spruce forests, or else there must be available a variety of food in different seasons, as in the mixed conifer and hardwood stands. The food and the nesting habits of the chickaree are more varied than those of other North American squirrels. In consequence the choice of habitat is less limited.

Not only do the habitats of the red squirrel vary from one locality to another, but in adjacent regions preference for similar habitats varies in accordance with food preference. Thus at Speculator, Piseco and Long Lake, New York, the squirrels were abundant in spruce stands and uncommon in balsam; while in balsam stands at Lake Placid and on Valcour Island they were common. Similarly at Petersham, Massachusetts, where the white pine is the principal food tree the squirrels are found chiefly in stands of this species, while in white pine areas examined in the Adirondacks squirrels seemed to be absent. At Piseco, for example, only one pine midden was found. For this reason the habitats of various regions are best considered separately.

In Interior Alaska, according to Dice ('21, p. 25), *S. hudsonicus* lives in the forests of white spruce and occurs rarely in black spruce. In that territory it is seldom seen far from spruce, probably because of its dependence on these trees for food. Osgood ('09, p. 22), too, writes that in East Central Alaska he found their permanent abodes pretty well confined to the vicinity of spruces. Bailey ('18, p. 37) found that in Glacier National Park the lodgepole pine more than any other tree marked the full range of *S. h. richardsoni*, and furnished more food and lodging for it than any other tree. *S. fremonti* in Colorado is, according to Warren ('10, p. 186), found in the pine and spruce zones. *S. fremonti mogol-lonensis* is limited to the Douglas fir, the spruce and fir belts, and is entirely absent in the yellow pine zone and the lower piñon area (Merriam, '90, p. 48). In Wisconsin, *S. h. loquax* is found in hemlock groves, larch swamps, groves of bur oak and mixed woods of pine, cedar and birch (Jackson, '08, p. 16).

At Petersham, Massachusetts, typical of a large section of New England, the red squirrel distribution is mainly dependent on a cone supply of one sort or another. The white pine, being the principal cone-bearing tree in this forest, is the tree with which the red squirrel is largely associated in its local distribution. The white pine furnishes the squirrel food, a home site and building materials, protection from the weather, and a drying rack for mushrooms. There are here, too, innumerable aerial highways among the interlacing tops or crowns of the trees as well as lower down among the numerous dead and dry branches. Red squirrels do not, however, reach their maximum abundance in the pure stands (or as nearly pure as such occur), for here is a dry, well ventilated forest floor where the needles rot slowly and insulate the soil against inoculation by hydrophilous plants. The lack of blueberries, hazel brush and other food plants keeps low the squirrel population. When hardwoods and gray birch gain a foothold in a pine stand their leaves help mat the ground, and the rate of decay is accelerated; suitable soil is formed for a wider variety of plants, and the more moist soil of the surface becomes better suited to seed germination. Under ensuing conditions the red squirrel finds a greater food supply: in spring, the bark and buds of the hardwoods; in summer, their fruits, as well as mushrooms, hazelnuts and blueberries. In the autumn come other fruits and a new crop of cones and nuts. The stored foods from other seasons must largely care for the squirrel in the colder months.

Near Petersham the red spruce, though very limited in its distribution, furnishes an abundance of cones and of shelter which the squirrels of the immediate vicinity do not fail to accept. Hemlock is often used as a nest tree, but though captive squirrels opened all the hemlock cones supplied them, they apparently never ate the seeds, for these came through the sieve of the cage floor in large quantities. By adaptation the scotch pine plantations have become favorite feeding grounds, too, for their seeds and winter buds are relished by the red squirrel. Norway spruce and larch plantations have been invaded during the winter for their buds, but no nests have been built here because of the youth of all the stands. Other habitats, too, here serve as seasonal foraging grounds, although the white pine is always near at hand.

The habitats in which red squirrels were seen, listed in the apparent order of density of population, were as follows: (1) white pine, hemlock and transition hardwood; (2) white pine and transition hardwood; (3) hemlock and transition hardwood; (4) white pine and hemlock; (5) red spruce swamp, white pine stand; (6) pine and gray birch; (7) Scotch pine plantations over ten years old; (8) hardwood swamp; (9) the edificarian habitat.

In Westchester County, New York, I have found the red squirrel common principally in stands of mixed hardwoods; hardwoods and hemlock; orchards; and associated with farm buildings, stone walls and isolated Douglas firs.

In the Southern Adirondacks, as represented by the Speculator, Piseco and Old Forge districts, the squirrels show seemingly no association with white pine or balsam, but appear to follow the spruce. Red squirrels here are abundant in mature hardwood forests; in mixed hemlock, spruce and balsam; in old spruce; and in virgin forest which here is a heavy stand of cherry (or black) birch, beech, maple, and spruce.



Fig. 13. Hardwood forest of red oak, maple, hop hornbeam and canoe birch. Squirrels forage in this stand, but are not resident. Valcour Island. September 8, 1926.



Fig. 14. Hardwood forest (age 35 years) of beech, cherry birch, maple and cherry. Squirrels present though rare. Piseco, N. Y. June 30, 1926.



Fig. 15. Virgin forest of spruce, hemlock, cherry birch, striped maple, sugar maple, and beech. Undergrowth of witch hobble. Squirrels uncommon. Owl's head, Long Lake. July 17, 1926.



Fig. 16. Forests of mature hardwoods of maple, birch, beech and hemlock. Squirrels occasional. Long Lake. July 26, 1926.

In the sapling and immature hardwood areas there are few or no squirrels, no doubt because of the lack of winter food. In mature stands of hardwood conditions are favorable for the squirrels because of a varied flora, and the presence of a few cone-bearing spruce trees. The old hardwood stands, essentially virgin forest with the spruce thinned out, support few squirrels. Here the stands, principally of birch, cherry birch and maple, offer little winter food. The absence of oaks, chestnuts and walnuts keeps the stand from being more favorable. The red squirrels appear to neglect the beechnut crop, though occasionally some litter of beechnuts was found.

Spruce-tamarack swamps support considerable red squirrel populations. In stands of balsam and spruce squirrels are common, but their middens contain spruce litter only. In hemlock stands where there are some spruce trees, the squirrels occur, but seem to feed only on the spruce.

Conditions in the mature forest (as along the south branch of West Canada Creek, near Buck Ponds) are different in several respects from those in adjacent areas. The hardwoods are much the same in size as those in surrounding territory free from squirrels, but many tall spruces occur. Where the country was lumbered, only the pulp trees were removed, so the remainder of the stand changed but little. The largest spruces in the virgin forest stand about one hundred feet high. One measured twenty-seven inches in diameter, five feet above the base. The cherry birches are the largest trees, being a hundred or more feet tall and measuring forty inches in diameter shoulder high.

The undergrowth is mainly of hobblebush and striped maple. One important feature is the absence of old stumps on which the squirrels may sit and feed and in which they may tunnel and build nests. The undergrowth, too, is very dense, and ground feeding hazardous. Yet I saw three squirrels on the ground within the course of an hour. No middens of spruce could be found, except scattered remnants of cones where a squirrel had stopped for a hasty lunch. Possibly, due to the height of the spruces and the unfavorable ground conditions the squirrels feed in the tops of the trees and the litter is scattered in its fall.

In this region squirrels come infrequently around the abode of man. According to a Piseco guide, they move about from season to season, living in the "sugar bush" (young sugar maples) in the spring; in the older mixed hardwood forest during the summer; in the beech trees in the autumn, and among the spruce in winter. Feeding activities probably do carry them in some such circle, but their home tree undoubtedly remains the same.

In the Adirondacks, in such localities as Long Lake, Saranac Lake and Lake Placid, the squirrels are most abundant in heavy spruce stands; but balsam, too, supports many. The second growth mixed forests have squirrels in direct ratio to the abundance of spruce. Virgin forest (as on the slopes of Owl's Head, at Long Lake) are sparsely populated.

A stand of stunted spruce near the summit of Blue Mountain supports few squirrels, doubtless because of the restricted food supply, the severity and length of the winter season, and the shallowness of the soil.

Stands of white pine and mixed white and red pines apparently contained no squirrels.



Fig. 17. Mature spruce forest. Squirrels abundant. Nick's Lake, Old Forge, N. Y. July 9, 1926.



Fig. 18. Tamarack—arbor vitae swamp. Squirrels foraged here only. Long Lake. July 25, 1926.

On Valcour Island, Lake Champlain, the squirrels occur in all forested habitats though they are most common where spruce (white and red), balsam and arbor vitae (Fig. 20) are most plentiful. In young hardwood stands (Fig. 13) no squirrels appeared to be in residence, but they not infrequently foraged through such habitats.

Home range. At Petersham, Massachusetts, a pair of red squirrels near my camp were under almost daily observation for three months. From watching the activities of these squirrels and from careful search for all nests in the area I concluded their greatest range of activities was a circle less than two hundred yards in diameter. On one side their range was limited by a lake, on another by an open field. The stand was a mixed forest with pine dominant.

Klugh ('27, p. 3) considers the home range of the red squirrel to be about two hundred and fifty yards square. He remarks: "That a restricted home range is decidedly advantageous is readily seen, as within this area the squirrel knows every tree and limb, every jump from one tree to another, and every hole, either in a tree or in the ground, so that its chances of escape when pursued by an enemy are much enhanced."

Seton ('09, pp. 310-311) assigns less than ten acres to each squirrel, and documents this with several examples in his experience. He cites, too, the case of a pair of albinos which Paul Doherty said only once were seen more than eighty feet from their nest tree. Later Seton ('28, p. 122) assigns but six acres to the home range.

Squirrel populations. The density of the squirrel population in different regions varies, doubtless not only with differences in habitats, but from season to season. Though no rhythmic cycle has as yet been established for the red squirrel, observations over several seasons at Leland, Michigan, led me to believe them most abundant there about every third year.

Merriam ('84, p. 212) correlates the red squirrel population in the Adirondacks with the beechnut crop. He gives a well marked instance in the year 1881 and in 1882. It is his contention that in the year of a good crop (not the year following, when it would seem most logical) the animals were excessively abundant while the next year they had almost entirely disappeared.

In the New York Zoological Park, in 1903, according to Hornaday ('13, p. 79), the squirrels became so numerous that they were driving out the nesting birds and the fox squirrels. Sixty reds were shot in the 234 acres, and the population reduced to a reasonable number. Even then the squirrels averaged more than one to four acres. Seton ('09, p. 312) found at Kenora, Manitoba, where they were more numerous than elsewhere, that there was not more than one squirrel to each three acres of pinewoods. He allows on the average one pair of squirrels for every square mile. Later ('28, p. 119) he writes: "Dr. R. G. Waugh of Carberry, Man., killed 14 red squirrels in his acre of bird sanctuary. Dr. M. C. Rumball of Morden, Man., tells me that in the summer of 1912 the red squirrels in his town became so numerous and destructive to bird nests, that he shot 15 on his house lot, which was 200 by 125 feet. It was well wooded like the rest of the town. This killing made no visible difference in the numbers of red squirrels."

Grinnell and Storer ('24, p. 207) estimate one squirrel to each four acres, for *S. douglasii albolimbatus*.

Klugh ('27, p. 3) places the abundance of the red squirrels in the original pine forest of Ontario at not more than one to every twenty acres, and in the original maple-beech woods about the same. About two squirrels to every hundred square yards were found in the spruce woods of New Brunswick. Klugh found, in a census of a region of abundance of squirrels at Grand Bend, Ontario, during the spring of 1923, nine squirrels to every acre. This was in a mixed forest of pine, hemlock, cedar, red oak, white oak, beech, maple, butternut, and hickory. The greatest local abundance which he records is seventeen red squirrels in a group of five butternut trees, during early September. This was in a region where such trees were scarce. A similar gathering of about the same number was described to me as occurring in the trees of a rocky hillside, in late February, 1927, at Katonah, New York.

At Petersham, Massachusetts, within 200 yards of the shores of Harvard Pond, there were to my knowledge in the summer of 1925, nine pairs of adult red squirrels; or about one pair to each nine acres. Five of the pairs were in stands principally of white pine. In the Harvard Forest during that year I estimated that there was about one pair of squirrels for each six acres of mature white pine growing in dense stands, one pair to each two acres of spruce swamp, one pair in each three acres of hemlock and approximately one pair to each four acres of mixed pine, hemlock and transition hardwood.

In a pure stand of mature red spruce (Fig. 19) at Long Lake, N. Y., bordered on one side by open fields and on the other by an extensive hardwood forest, I found the red squirrels in abundance. The stand was 500 yards long by 100 yards wide, or about ten acres. In a few days I secured a total of sixteen squirrels and knew of two more that were left. The specimens taken were three adult males, three adult females, and ten young ones. This would indicate three families, or one family to three and one third acres. In this stand were three outside nests and numerous burrows, one of which showed on excavation a recently used nest.

The information that red squirrels are now but one half to one fifth as abundant as formerly, was volunteered by almost every inhabitant of the Adirondacks with whom I conversed. But it is my opinion that as in the case of the proverbially greater snowfall of former years, the squirrel population remains about the same, or is if anything on the increase. In all probability these people retain an impression of the abundance of squirrels in some maximal period of a population cycle and think of this as typical of the old days. Furthermore, these people go less into the woods than they did formerly, and when they do go their attention is probably not especially directed towards squirrels and their numbers.

Seasonally the squirrels must be most abundant early in the summer, after most of the litters are born. Yet the Adirondack guides and hunters invariably told me the squirrels were most abundant in the fall. The reason for such an opinion undoubtedly lies in the fact that squirrels are more in evidence at that season, there is greater activity on the part of a larger number of squirrels and their noisiness increases as the young grow older; and there is greater activity on the ground, and in cutting cones and nuts. The greater amount of noise made by squirrels on the ground because of the presence of the newly fallen leaves easily attracts the attention of hunters and others who are in the woods at this season.



Fig. 19. Pure stand of red spruce. Supporting the most dense squirrel population encountered. Long Lake. July 25, 1926.



Fig. 20. Arbor vitae forest mixed with balsam. Squirrels abundant. Valcour Island, Lake Champlain. September 8, 1926.



Fig. 21. Balsam stand at Long Lake in which squirrels were abundant. July 12, 1926.



Fig. 22. Second growth stand of white spruce, arbor vitae, balsam, white pine and canoe birch. Red squirrels present where growth is thickest. Valcour Island, Lake Champlain. August 27, 1926.

REPRODUCTION

Mating. The œstral period would seem either to vary in individual red squirrels in the same region or there is more than one œstral period in the year, at least if the first period is not fruitful. The season of heat occurs in early spring, just when the snow begins to melt, according to Bell ('98, p. 77). As early as February 6, Seton ('09, p. 313) found signs, internal and external, of sexual activity among the red squirrels about Toronto. Mearns ('98a, p. 339) states that in the Hudson Highlands, they are commonly seen mating during February. Mating behavior was observed March 1, by Dice (21, p. 26), in Interior Alaska. The squirrels are reported (Preble, '08 p. 170) mating in the Athabasca-Mackenzie region late in March. Klugh ('27, p. 4) reports that in Ontario the red squirrels mate in March, and at that time there is more chasing about among the branches than at any other time. In Manitoba the species is reported as mating late in March or early in April (Seton, '09, p. 313). As to duration of the period, Seton (ibid.) has seen a pair attempt to mate as late as July 19. Other late matings are indicated by records given beyond. Small embryos were found in an Adirondack squirrel taken July 19, and what was apparently a copulation plug was observed in a female taken July 26 in the same region. About September 1, 1919, I saw a pair of clasping pine squirrels (*S. fremonti*) in the front range of the Rockies near Devil's Head, Colorado. This, together with observations on wild and caged squirrels of several species have led me to believe that sporadic attempts at coitus are common even far outside the period of possible reproduction.

The scrotum during the breeding season is large and pendulous to accommodate the enlarged gonads. Richardson ('29, p. 189) reports this condition of the scrotum as prevalent during the spring. Data in my field notes on Adirondack red squirrels between June 29 and August 14, and on Lake Champlain squirrels between September 8 and 10, show a considerable individual variation of the condition of the testes in adult squirrels on the same date. The longest testes, from squirrels taken July 25, 26, and September 10, measured 17 mm in length. Pairs of such testes, with epididymis attached, weighed from 2.1 grams to 2.5 grams and were located in the scrotum. In squirrels weighing less than 155 grams the testes had not entered the scrotum. The smallest testes found in a scrotum measured eight millimeters and weighed half a gram. Testes were abdominal and minute in the males taken July 16, 21, and 23, the individual weights being 124, 121 and 131 grams respectively. Descending testes were found between the inguinal canal and the scrotal fold of immature squirrels taken as follows:

July 25: body weight 116 grams; testes length 7 mm.
July 26: body weight 126 grams; testes length 8 mm.
July 26: body weight 126 grams; testes length 8 mm.
July 26: body weight 155 grams; testes length 14 mm.
Aug. 14: body weight 136 grams; testes length 11 mm.

There appears to be no preliminary courtship in the mating of red squirrels. The male seizes the female and clasps her abdomen with his fore legs. The pair of pine squirrels referred to above, when first seen were on the ground. The

female, after being frightened by my approach, carried her burden with some difficulty to a tree about fifteen feet distant. The male, retaining his firm hold, was carried up the tree a distance of several feet before separating from his mate. I have observed a captive male seize a female as she clung head up to the vertical side of the cage.

Pairing. The permanency of mating of the red squirrel has not yet been determined. While there is doubtless individual variation in this matter, the bulk of testimony would indicate a loose partnership existing between one male and one female at least from one breeding season to the next.

Walton ('03, p. 77) mentions having seen an old male squirrel drive off a young male that tried to court one of the old squirrel's young female offspring, while another young male, on the contrary, was tolerated, if not welcomed.

He (op. cit., pp. 250-251) observes further that the male squirrel assists his mate in filling a storehouse for family use, then stores for himself on territory which he controls; and that while the male has a nest of his own, he stays in the home nest with the female and young if the weather is very cold.

Klugh ('27, p. 4) writes that a male and a female which he had observed individually for a year or more, apparently had no mates associated with them.

Seton ('09, pp. 313-314) relates the following incidents which indicate some permanency of mating in this species: He has seen two adults work together in building a nest. Two albino squirrels at Woodstock, New York, were seen together all summer and autumn. On July 19, a small red male, attempting by violence to possess a larger female, was driven away by another and larger squirrel which had answered the calls of the female.

Cory ('12, p. 126) states that the squirrels pair, at least in Eastern Massachusetts.

Warren ('10, p. 187) writes of a male *Sciurus fremonti* which, upon discovering his mate in a trap, chattered and expressed his grief by caressing and fondling the body (in a manner almost human) as if trying to coax it back to life.

Embryology. The period of gestation in many squirrels, according to Goldsmith ('35, p. 189), is about six weeks. The placenta, as in other rodents, is discoidal. The embryos are not always evenly distributed in the uterus, and I have found them divided variously, such as three in each horn, three in the left and two in the right; and placental scars four left and two right.

Six adult females taken between June 24 and September 10 contained no embryos. One taken July 18 at North Ashburnham, Massachusetts, contained six embryos measuring 31 mm from crown to rump. One taken July 19 at Long Lake, New York, carried five embryos measuring 39 mm from crown to rump. Seven female young of the year, taken between June 24 and September 10, contained no embryos. Dice and Sherman ('22, p. 38) found six small embryos in a female taken in the Cisco Lake region, Northern Michigan, July 16.

Number of young. The embryological records given above indicate six young as the common number. Seton ('09, pp. 316-317) reports a family of six young and another of five. Merriam ('84, p. 218), MacFarlane ('05, p. 749), Cory ('12, p. 126), Nelson ('18, p. 454) and Bailey ('18, p. 38) state that there

are four to six young in a litter. Mearns ('98a, p. 340) reports a family of six. MacFarlane (ibid.) writes that families with seven young are occasional. Klugh ('27, p. 5) saw a family of five young outside the nest. Stoner ('18, p. 26) refers to four or five young being produced at a single birth. Fisher ('96, p. 197) says that the young are about three to four in number. An apparent exception occurs in *S. h. picatus*, in which Swarth ('11, p. 118) writes that the number of young seems to be two; at least females shot in mid-April contained two embryos each.

Time of birth. The young, of which there appears to be but one litter a year, are usually born in April, May or June, but they may be born at any time during late spring or early summer. Merriam ('84, p. 218), Fisher ('96, p. 197), Cory ('12, p. 126) and Stoner ('18, p. 26) all speak of the squirrels as being born in April. Mearns ('98a, p. 340) writes that the young are usually born in May or June, but that they may be born at any time during the warmer half of the year. Preble ('08, p. 170) records a litter but a week or so old found May 9, in the Athabasca-Mackenzie region. Bailey ('18, p. 38), referring to *S. h. richardsoni* in Glacier National Park, states that the young are born in June.

Klugh ('27, p. 5) writes that in Ontario, New Brunswick and Manitoba they are usually born early in May, but that many broods are born considerably later. He writes: "I have on several occasions seen young squirrels but little more than half grown in September and October, and at Lake Missanag on September 6 I saw an adult and five half grown young on the trunk of a large dead hemlock, in which, at a height of about twenty-five feet, was their nesting hole." Seton ('09, p. 315) states it as his opinion that the young are born about the first of May. He reports a nest of blind young measuring about four and one-half inches long, found on June 24 in Manitoba. Another brood, near Lindsay, Ontario, was still blind and furless late in June. Broods born late in the summer may possibly be second litters though my only bit of evidence consists of the body of a female which I secured at Long Lake, New York, July 19. Though this squirrel contained five embryos thirty-nine millimeters in length, the mammary glands were greatly hypertrophied, as they might be following rather than preceding a period of lactation.

Appearance of young. "The young squirrels are most absurd looking little beasts at first, like miniature pug dogs," writes Cram ('99, p. 215), "blind and naked, and with enormous heads. In a few days their fur begins to show like the down on a peach, and as a fringe of short hair along each side of the tail, which at length assumes something of the flattened aspect of that worn by their elders." Bailey ('18, p. 38), too, speaks of the new born squirrel as naked and helpless for a long time. Mearns ('98a, p. 340) describes nearly naked young found April 19, with eyes closed, and those of another brood taken May 5, which were large, lively, soft, and pretty in their winter coats. Mearns declares that young born early in the season are at first equipped with the winter pelage while those born later have the summer pelage.

Five young which Seton removed from a nest near Carberry, Manitoba, on June 24, are described ('09, p. 315) as being blind, naked and helpless and with no sign of an aural orifice. "They measured each about $4\frac{1}{2}$ inches in length, including the tail which was $1\frac{1}{2}$ inches."

Birth place. The young are born either in the bulky nests among the branches of a tree, or in the hollow of a tree trunk. Bailey ('18, p. 38) writes that the young of *S. h. richardsoni* are born in the big grass nests among the branches or in the well lined hollow trunks. Seton ('09, pp. 314-316) describes very young squirrels from nests in an abandoned flicker hole, in a dead hollow tree, in a nest box, and also young found in outside nests in trees. Mearns ('98a, pp. 339-340) records them found in a hollow oak tree and in a bird house, though he remarks that they are usually brought forth in outside nests. Herrick ('92, p. 157) states that the young are cared for in hollow trees until able to shift for themselves; Cram ('99, p. 214), that they are usually born in a hollow tree, though sometimes in an outside nest. The hollow stump, he writes, may be but a few feet high and even open at the top, but in such a case it is usually protected by an overhanging hemlock or spruce. Bell ('98, p. 77), quoting the Indians, writes that they are most commonly found in outside nests. Preble ('08, p. 170) records a litter a week or so old from an outside nest, and also Walton ('03, p. 84) cites a case of the young being born in such a nest. In the far north, of course, there are not so many hollow trees as in the territory familiar to most of the red squirrel's biographers.

Lactation. It is not known how long the mother red squirrel nurses her young. Seton ('09, p. 316) expresses his opinion that the squirrels are not weaned until late in August. The latest date at which I personally have taken a nursing female was August 19, at Petersham, Massachusetts. Davis ('25, p. 427), at Ann Arbor, Michigan, on May 16 took a female whose mammary glands were very large.

Early life and training. The period of the squirrel's life during which it is developing its coat of fur is spent inside the nest. The mother is said to exhibit great anxiety over any disturbance to the young at this period. Seton ('09, p. 315) reports a female moving her blind, naked, helpless young to another nest after they had been discovered. This mother dashed up and down the trunk and over the observer's arms in great anxiety while her young were being examined. He describes another case (op. cit., p. 316) in which a female carried the half grown young off to a distant tree. At Kuppewa, Quebec, he saw a young red squirrel one-third grown being carried off by its mother.

The young first appear outside the nest when fully furred and about one-third grown. Bailey ('18, p. 38), with regard to *S.h. richardsoni*, writes that "They are carefully watched, and nursed and fed by the mother squirrel until they have learned the ways of the woods, and by the latter part of August have scattered out, each storing his own winter supplies or all working and storing together as a family, for the winter's supply about the old parental tree. Usually the families do not entirely break up until the following spring."

As early as June 1, Seton ('09, p. 316) has seen the young squirrels following the old one in a sort of procession through the trees. "This is no doubt their training," he writes. "The mother knows and teaches them all the leaps and bridges as well as the harvest trees in their overhead world." A two-thirds grown young is also reported, June 1, at Wyndygoul Park, catching and eating insects. June 11, at Cos Cob, Connecticut, Seton found small red squirrels running alone.

On June 16 his journal records a certain family of young sometimes following the old ones, sometimes traveling alone. By October he (op. cit., p. 317) believes the family has broken up spontaneously.

On June 16, I saw at Speculator, New York, a family of half-grown young playing over the surface of the stub which housed their nest. They occasionally ventured to the ground, leaped into adjacent trees and scolded like adults. When frightened they sought safety in the nest. One parent squirrel brought food to the young, but most of the time they were alone.

Walton ('03, pp. 76-77), as the result of intimate observation of certain individual squirrels over a long period, concludes that "young squirrels remain with their parents the first winter, but in April the female turns the family over to the male and makes another nest of moss, leaves and dry grass in the top of a tall pine or hemlock tree. While she is engaged by new duties the male looks after the young squirrels that are now full grown. He finishes their education and locates the young males on territory which they ever after hold."

In reference to a particular pair of young squirrels, Walton (op. cit., p. 87) writes, "The two baby squirrels for the most of the harvest time remained in the nest or on the hemlock tree in which the nest was located. Now and then they followed the mother to a nut tree, but were so noisy that I imagine the fear of enemies caused the discreet mother to drive them home."

Method of carrying young. The red squirrel in carrying its young evidently seizes them by the skin of the belly (Seton, '09, p. 317) or, as Lang ('25, p. 19) has shown for another species, by the skin of the proximal portion of the fore limbs. The young one then curls its legs and tail up around the neck of its mother to make a compact bundle and permit a firm hold.

VOICE

The vocal accomplishments of the red squirrel have earned for it at least four names by which it has been known: chickaree; boomer; barking squirrel, and, as a designation of one of the sub-species, *loquax*, in reference to its loquacious habits. In red squirrel territory one's attention is frequently drawn to the chattering monologue with which the animal addresses an intruder on his domain. Sometimes the squirrel's excitement mounts until, apparently, he boils over with rage and fury, barking, spitting, and sputtering, stamping his feet and jerking his tail in a manner truly ludicrous for one so harmless. This type of attack reveals, however, but one of the vocal accomplishments of the red squirrel.

In late spring and early summer the chickarees seem to be more quiet than at other times of the year. Bailey ('26, p. 47) believes that the adults are quiet until the young are old enough to take care of themselves.

A long vibrant rolling "tcher-r-r-r-r," carried for various lengths of time, and sometimes repeated, seems to be a note of intercommunication. One commonly hears the call answered by another squirrel in a different part of the woods. The call is often heard deep in the forest when it is certain that the squirrel is unaware of the presence of man. I have watched a foraging squirrel stop to make the call and to be answered by another squirrel a hundred yards away on a stone wall. Neither squirrel paid further attention to the other.

On another occasion, after watching a squirrel removing some of its buried stores, I sat down near its excavation during one of its trips away from this burrow. Shortly it returned and perceiving my presence stopped about three feet away and cautiously surveyed me. Half turning it broke out into the cicada-like *tcher-r-r-r-r*, then turned again to watch me. Later, the squirrel, after circling around, was frightened by a movement of one of my fingers and dashed away to scold me from a safer distance. Spreadborough ('19, p. 61) writes of this call being heard in the springtime and in late summer. My field notes contain numerous references to the call throughout July. The call is often described, usually as "*chir-r-r-r*," or "*cher-r-r-r*." Richardson ('29, p. 187) referred to it as sounding like a watchman's rattle. The notes composing this call follow one another in rapid sequence, with diminishing volume, lowering pitch and sometimes an increased interval between the individual notes. On a few occasions, preceding an outburst of the notes of anger, I have heard the squirrel sound this call, and produce a few rapid whimpering notes immediately afterwards.

The note of curiosity, or uncertainty, is frequently sounded when the squirrel is attracted to some object which at first is not fully comprehended. The animal displays mild excitement when making this call, which may be accompanied by a stamping of the hind feet, or jerking movements. Usually the animal is in plain view of the object of its excitement. The note is a sonorous whistled "*whuuk*," slowly repeated. While it is musical there is often a sharp metallic quality to the note, varying with the degree of excitement. The call may be fairly well imitated by a sharply checked nasal whistle. It slightly resembles the alarm note of the eastern chipmunk. The note of curiosity occasionally precedes the call of intercommunication.

The note of pain, a rather shrill screaming, is described by Klugh ('27, p. 31) who heard it from an intruding individual which had been bitten by another squirrel, the owner of the stores it was raiding. Dice ('21, p. 26) refers to a young squirrel screaming as it fought when attacked by a mink.

The scolding of the red squirrel, which Klugh ('27, pp. 30-31) has apparently correctly designated as an expression of anger, varies greatly in its components, depending on the intensity of feeling of the individual.

The characteristic angry chattering is usually preceded by the whistled note of curiosity, the *tchir-r-r-r* of communication, or a "*meur-meur-meur*," which Klugh ('27, p. 31) refers to as an expression of curiosity, or a whimper of nervousness. Usually mounting a branch, the squirrel, now thoroughly angry, breaks out into a long chatter interrupted at varying intervals by an explosive, whistled "*chuck*," or a high-pitched piping note, as represented on the accompanying musical staff (Fig. 23).



Fig. 23. The chatter of anger.

The high notes, though all of the same pitch, seem to vary because of their changing volume and length. When the squirrel becomes exceedingly angry

its outburst almost defies analysis, for it seems that it has several voices, all carrying different notes at the same time. My best observations have, however, convinced me that no two notes are exactly synchronous, and that all are vocal, one of them being produced by the teeth. But I have heard a squirrel producing, while it held a birch catkin in its mouth, notes that at one time I suspected were dental.

The squirrel may apparently be provoked into such a volley of whistles, spits, sputters and squirrel growls by any animal intruder or by the failure of some activity in which it is engaged. Seton ('09, pp. 326-327) describes such an instance, where a squirrel was having great difficulty in transporting a large mushroom; and Klugh mentions ('27, pp. 30-31) one in which a squirrel twice in succession dropped a large bun it was carrying when attempting to leap with it. I have been attracted to a scolding squirrel which, though obviously greatly displeased over something, alternated each piping-scolding note with a bite from a yellow birch catkin on which it was feeding. Anger was not to interfere with pleasure. One of a pair of captive red squirrels which I once kept, almost daily delivered such an early morning lecture to its mate, as they quarreled over their breakfast. Synchronously with the vocal expression of outraged feelings the red squirrel stamps and dances up and down with its hind feet. This accompaniment of excitement I have also observed in flying squirrels, and I have heard of a similar habit in some kangaroos. It might be questioned whether this is not a primitive method of signaling, or something which, though unconsciously, serves the same purpose. The so-called signaling of rabbits by stomping, and the drumming of *Peromyscus*, may likewise be outgrowths of such a nervous reflex.

A singing red squirrel is described by Seton ('09, p. 313), who remarks that "She seems to amuse herself by uttering all the squirrel notes in rapid succession, going over the list a number of times, and in various combinations, until her performance has lasted ten or fifteen minutes."

RED SQUIRREL NESTS

The red squirrel builds nests in the branches of trees, in cavities within trees or stumps, within stone walls and in burrows under the ground. In every region one will not always find all types of nests. In the far north, where the forests are strictly coniferous and the timber small, there are few hollows in trees for the squirrels to occupy. In consequence outside nests are more commonly found. I have no record of underground nests in the southern part of the chickaree's range.

Outside nests. The outside nest seems to be found throughout the range of the red squirrel, though in regions where hollow trees and flicker holes are common this type of nest is rare. In the Southern Adirondacks, though red squirrels were common, I found only two outside nests, and these in the same tree. Hollow trees and stubs offered abundant shelter with less work and evidently satisfied all the requirements of the squirrels for nesting purposes. Even in conifer stands, where squirrels fed, I found no outside nests, the squirrels apparently visiting the area from adjacent hardwood growth. On Valcour Island,

Lake Champlain, the outside nests were uncommon, and probably for the same reason. Cory ('12, p. 126) reports outside nests exceptional in the latitude of Chicago. Seton ('09, p. 314) states that about Carberry, Manitoba, where hollow oaks and flicker holes abound, the outside nests are rarely seen, and adds that in the pine forest about Kenora, on the other hand, the red squirrels build many outside nests. I found such nests quite common also in the white pine stands at Petersham, Massachusetts (Fig. 25), and in the central, conifer-covered Adirondacks. This type of red squirrel nest is reported by Bailey ('26, p. 47) for North Dakota, and by Spreadborough ('19, p. 61) for the Canadian Rockies, while Osgood and Bishop ('00, p. 27), Dice ('21, p. 25) and Murie ('27, p. 38) describe it as the commonest type of nest in Interior Alaska, where, according to these authors, several nests are often found in the same tree or in adjacent trees. At Speculator, New York, I found two nests in one tree, but neither was in use and they may not have been contemporary structures.

The habitat chosen for outside nests in New York and New England may be any mature forested area. Murie ('27, p. 38) writes that in Interior Alaska the "Squirrel nests are particularly plentiful in the heavier forests lining the stream banks, and are more seldom found in the scattered small black spruces of many districts."

The species of trees in which the outside nests I have recorded from the Adirondacks and from Valcour Island, Lake Champlain, were located, and the number of nests in each are: red spruce (3), white spruce (2), hemlock (2), and witches' broom in balsam (2). From Petersham, Massachusetts, I have recorded nests in white pine (6), Scotch Pine (1) and hemlock (1). Merriam ('84, p. 218) describes, for Lake George and similar areas, nest sites in tops of evergreens, occasionally in deciduous trees, and in the midst of a tangled grapevine. He states that the red squirrel shows a preference for red cedar, probably for the reason that this tree furnishes most of the material for a nest. Mearns ('98a, p. 339) found nests in the foliage of the juniper, in the Hudson highlands. Seton ('09, p. 314) describes a nest in a small jack pine at Ingolf, Manitoba. In Interior Alaska, Dice ('21, p. 25) found the nests in white and black spruce, and Murie ('27, p. 38) found a nest in witches' broom.

The height of red squirrel nests from the ground varies. Most of those which I have found in white pine have been in the crown, usually about five feet from the top. The highest of which I have a record was at sixty feet, in a sixty-five foot white pine. Another was at fifty feet, on a small protruding limb on the otherwise clear stem of a hundred-and-fifty-foot pine in a virgin stand at State Line, New Hampshire. Nests were commonly seen at heights of thirty to forty feet in white pine on the Harvard Forest. Nests in spruce and hemlock averaged seven feet below the summit of trees twenty to forty feet high. The nests which I found in witches' broom (Fig. 24)—the distorted growth of a tree, in gross appearance resembling mistletoe, but caused by a fungus disease—were at heights of ten and twenty feet. Dice ('21, p. 25) writes that in the spruces of Interior Alaska the nests occur at heights from six to twenty feet. Seton ('09, p. 314) describes a nest in a pine at a height of nine feet, while I have seen one in a Scotch pine at eight feet.



Fig. 24. Red squirrel nest in a "witches' broom," ten feet above ground in balsam. Long Lake. July 12, 1926.

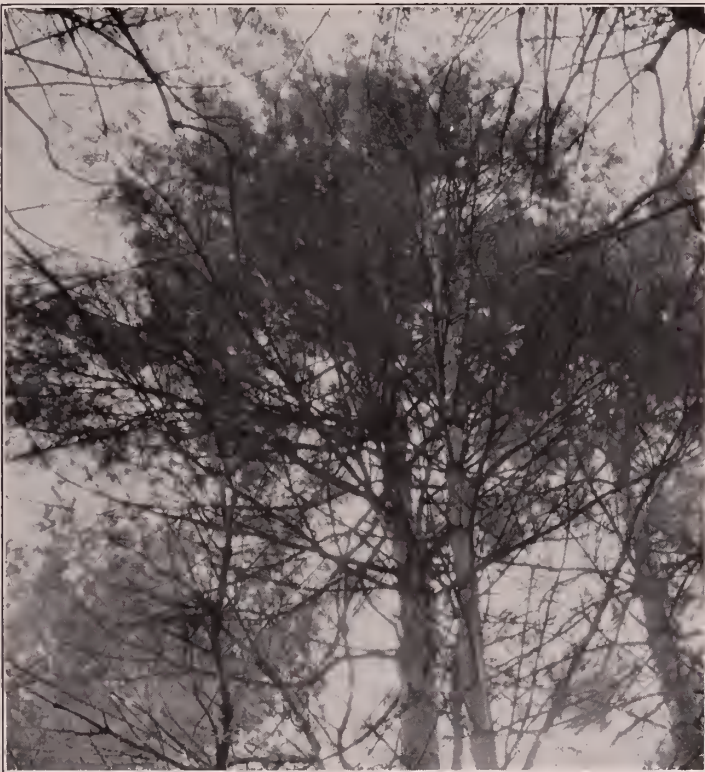


Fig. 25. Nest site of a red squirrel, in the crown of a 55 foot white pine. Petersham, Mass. August 10, 1926.

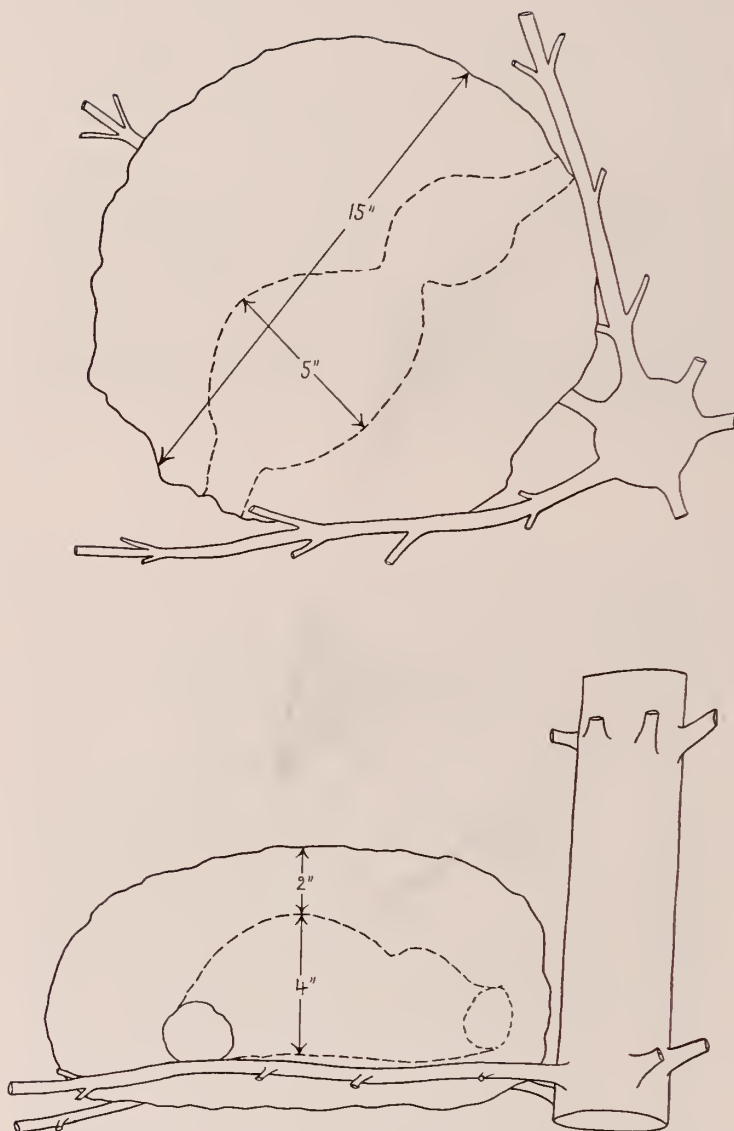


Fig. 26. Plan of double chambered outside nest of a red squirrel.
Drawn in horizontal and vertical planes.

Nests may be built against the trunk, straddling the base of one or several branches, or, less commonly, near the end of a branching limb. Eleven of fifteen nests I have described in my field notes were adjacent to the trunk. The others were at distances of three, four, five and eight feet from the trunk. Another nest was built in the center of the circular broom formed about a squirrel-killed leader of a Scotch pine.

Nests are sometimes exposed to direct rainfall and snow, but are usually protected by foliage above. Direct sunlight, while reaching some nests during part of the day, is probably not a factor entering into the selection of a nest site. According to Spreadborough ('19, p. 61) the nest is usually placed near the food supply, in a tree with thick foliage.

The outside nests serve as homes the year round, 'at least in the far north, though Bell ('98, p. 77) writes that they serve as homes only in autumn and spring. Cory ('11, p. 70) writes that *Sciurus fremonti* uses the outside nests both in winter and in summer. The young are often brought forth in these nests, as shown under the section on the birthplace of the young. There are no clear records known to me, showing that two or more adult squirrels share a nest together, though my captives have done so amicably, and I presume wild squirrels would, too, at least in cold weather.

The nest is well constructed from materials at hand and to fit the demand of its location. It may be built upon a platform constructed of twigs, in an abandoned hawk's or crow's nest, or it may rely for its support solely upon the branches upon which it rests. The bulk of the nest is always in two layers, an outer thick roof and walls and floor of coarse material, to shed water and resist wind, and an inner lining of fine, soft material for warmth and comfort. Usually there is but a single chamber, though in one nest I found two (Fig. 26).

The entrance is commonly in the wall of the nest, on any side but that next the trunk. In three nests I have found a point opposite the commonly used entrance to be so thin that the squirrels probably intended it as an emergency exit. In the double chambered nest here figured there were two open entrances. Nests are frequently found with the entrance stopped up by the fine material used as lining. Cram ('99, p. 213) writes of a "hanging curtain of moss or some other substance easily pushed aside by the inmates, but immediately falling back into place effectively concealing the entrance." Seton ('09, p. 314) describes a nest the door of which was draped with fibrous material which made it virtually self-closing and quite concealed. Walton ('03, p. 251) states that there is always a surplus of fine material used to stuff the entrance to the nest, to shut the door and keep out the cold.

The nests are large and bulky, unless constructed of cedar bark. A nest at Petersham, Massachusetts, measured sixteen inches in diameter and ten inches deep. The inner layer of this nest was ten inches in diameter and four inches deep, while the chamber was four inches across and but two and one-half inches high. Another nest was sixteen inches in diameter and twelve inches deep; a third, ten inches in diameter by five inches deep; a fourth, twenty inches in diameter. Two nests at Long Lake, New York, were fifteen inches in diameter and eight inches deep. In one the roof was two to three inches thick over a chamber five inches in diameter and four inches in depth. Seton ('09, p. 314) describes a nest,

in Manitoba, eighteen inches across and fourteen inches high. Dice ('21, p. 25) refers to a nest of dried grass, in Alaska, as one foot in diameter.

The nests by virtue of their location and construction are efficient in guarding the squirrels from the weather. The floor of some, below the fine dry lining, is wet and firmly packed so as to be, in its thickness of one to three inches, quite impervious to draughts. The nests that I have examined during their period of occupancy have always been warm and dry inside regardless of the weather. Seton ('09, p. 314) describes a nest as being warm and dry inside in spite of recent heavy rains. Cram ('99, p. 213) writes that the nest usually freezes hard early in the winter.

The nest cavity usually contains no food waste, and occasionally is free from excreta, but it almost invariably contains those external parasites which are harbored by its owner. Both fleas and ticks are common. Of other things, from the chamber of a nest not recently used I removed on one occasion the empty shells of several snails, the shells of three acorns, and the opened pits of eight wild cherry seeds.

Nest Construction. In various regions somewhat different methods of nest construction may be found. Thus, in the Hudson Highlands, in the Lake George and Lake Champlain districts and in other places where some species of cedar or juniper is common, I found the nests built largely or wholly of the bark of these trees. In regions dominated by white pine, as at Petersham, Massachusetts, the nests were composed of the litter of the forest floor, heaped on a platform of sticks, the platform necessary both because of the loose nature of the material used in construction and because of the poor support offered by the barren branches of the white pine which usually served as a nest site. In the Adirondacks on the other hand, the nests while composed of about the same materials as those in the pine regions, have no platform, apparently since a spruce or hemlock is usually chosen as a nest site, in which the many fine branches are in themselves ample support for a bulky nest. In the Adirondacks region the nests are almost invariably lined with shredded bark of the yellow birch, while at Lake Champlain the bark of *arbor vitae* serves this purpose. In the Canadian Rockies and in Interior Alaska the nests are, according to the five authors cited below, built chiefly of fine dry grass, and presumably without a platform of twigs, because a dense spruce is usually the site of the nest.

A nest which I examined in a white pine stand at Petersham, Massachusetts, was placed on a platform of dry terminal white pine twigs, not cut, but gathered from the forest floor, averaging one-eighth inch in diameter and eight to ten inches in length. The outer covering of the nest was practically an exact sample of the forest floor at the foot of the tree: two parts of dry unbroken leaves of deciduous leaved trees, and three parts of dry white pine needles. A few fragments of green moss were included. The lining of the nest chamber was of long dry unshredded grass blades. Another nest in the same stand was similar, except that twigs averaging fourteen inches long were scattered throughout the sides and roof. The inner wall of this nest was mostly of moss and grass, in which were included a few fibers of birch bark, some shredded wood, a piece of string and a few scattered feathers of a cedar waxwing. Three other nests in similar stands were similar in construction to the first described.



Fig. 27. Small, dead arbor vitae, denuded of bark by red squirrels. The bark is used in nest construction. Valcour Island, Lake Champlain. September 8, 1926.



Fig. 28. A section of the trunk of the tree shown in figure 27, bearing tooth marks of a red squirrel. Valcour Island, Lake Champlain. September 8, 1926.



Fig. 29. Red squirrel nest in old flicker nest cavity. A section of the wall cavity has been removed to show the complete height of the nest material added by the squirrel. Valcour Island, Lake Champlain. September 12, 1926.



Fig. 30. Pile of poplar logs within which was a red squirrel's nest. Valcour Island, Lake Champlain. September 8, 1926.

A nest in a Scotch pine plantation at Petersham was similar except that the twigs composing the platform were of Scotch pine. The inner wall was of grass and a few dry leaves arranged concentrically around the chamber.

Another nest, situated in a hemlock in a mixed stand at Petersham, had as its base only collected broken twigs of hemlock; the outer wall was of dry oak leaves and needles of hemlock. The nest was lined only with dry oak leaves. Walton ('03, p. 251) refers to a similar nest, near Gloucester, Massachusetts, of moss so thatched with oak leaves that no rain could enter. The nest was lined with milkweed silk and fine shreds of yellow birch bark.

At Long Lake and at Speculator, in the Adirondacks, I found the nests much the same as those at Petersham, Massachusetts, except for the absence of a supporting platform and the substitution of finely shredded bark of the yellow birch for grass. For example, one of five nests described in my field notes was composed of an outer wall of dried leaves of sugar maple, beech, red maple, and white pine, material typical of the adjacent forest litter. The lining was of shredded yellow birch bark and finely fragmented dry leaves of broad-leaved trees.

Nests built principally of shredded bark are found in Southern New England, in the regions of Lake Champlain and Lake George, in the vicinity of New York City, in the Hudson River Valley and, according to Seton ('09, p. 314), in the vicinity of Kenora, Manitoba.

This type of nest when well constructed is quite weather proof and possessed of exceptional strength. Such a nest I found in a spruce on Valcour Island, Lake Champlain. There was a base of sphagnum-like moss, a few dry leaves of hardwoods, and some stray strands of arbor vitae bark. The outer walls and the roof of the nest were of the coarsely shredded strips, one-quarter inch wide and less, of the inner bark of arbor vitae. There was a lining of very finely shredded bark of the same trees.

Mearns ('98a, p. 339) writes of such nests made outwardly of strips of bark, chiefly of red juniper and grape, and lined with hair, feathers and moss. Cram ('99, p. 213) states that the bark used is of two sorts, the rough outer bark of different trees, torn to small pieces, and what appears to be the inner bark of the red cedar, torn into narrow strips or ribbons to bind the whole together. Inside, these nests are lined with dry grass and feathers. Merriam ('84, p. 218) describes the nests as usually of soft silky bark of red cedar, and sometimes the bark of grapevine or the inner bark of chestnut intermixed.

Seton ('09, p. 314) describes Manitoba nests as masses of bark strips and roots.

On Valcour Island, Lake Champlain, I found arbor vitae from which bark had been stripped by the chickarees. Eight such trees within fifty feet of each other grew in one habitat where squirrels were common. All of the trees were small, the largest (Fig. 27) being but three inches in diameter at the base. This tree, dead like the others, though not because of the barking, was practically denuded over the middle two-thirds of its trunk. Teeth marks (Fig. 28) transverse to the direction of growth of the bark showed the way the strips had been pulled off in their spiral paths. Similarly barked though larger dead junipers are common about Bedford, New York, where the red squirrels use this same

kind of material in nest building. But some of the nests are apparently the work of the more abundant gray squirrel.

The red squirrel nests in Interior Alaska are built mostly of dried grass, writes Dice ('21, p. 25). Osgood and Bishop ('00, p. 27) describe the nests in the Yukon basin as globular, and composed of grass, moss, bark and refuse. Murie ('27, p. 38) states that the nests in Interior Alaska are of fine grass, lined with shredded bark, and that other material is used when it is obtainable. He describes one particularly fine nest from Kobi as being composed on the outside of grass, moss, bits of paper, a rag, and ravelings from a gunny sack, while the inner layer consisted of a heavy lining of mountain sheep hair. The materials were gleaned largely in a barn nearby. Nests in the Canadian Rockies are evidently similar, for Spreadborough ('19, p. 61) describes them as being of fine dry grass, sometimes mixed with the inner dark fiber of the balsam poplar and of another species of poplar.

Nests in tree cavities. Nests built in hollow trees, stubs, and in deserted woodpecker holes are probably of general occurrence except in the far north and in conifer zones of the mountains. I have found records of such nests throughout New England, New York State, the Chicago region, North Dakota and Manitoba. Where found, it is in these nests that the young are commonly brought forth (citations in section on Birthplace of Young).

Near Speculator, New York, I found a hollow stub of a dead tree occupied by a family of young squirrels in mid-June. The cavity, entrance to which was through two knot holes, was about four inches in diameter and extended three feet along a horizontal limb and a foot into the main stem. The only floor of the cavity was a leveled mass of chips of rotten wood. The squirrel may have had a warmer nest nearby. On Valcour Island a nest (Fig. 29) occupying a deserted flicker hole seven feet up in an old poplar stub, was composed of dry leaves and shredded bark. Cram ('99, p. 214) describes the hollow stubs as being filled with soft dry grass and a bedding of lichens. Seton ('09, p. 314) writes that the majority of those he examined were in the abandoned holes of the flicker.

Ground nests. There is no sharp line of demarcation between the nests in tree cavities and those underground, for I have found them in old rotten stumps and in piles of rotten logs. Cory ('12, p. 124) also has reported them in logs. Mr. Donald Carter informs me that he has torn out nests built in stone fences. I have found underground nests in the Adirondacks, and such have also been reported from North Dakota by Bailey ('26, p. 47), and described by other authors with no locality assignment.

Saint Hilaire and Cuvier ('24, pages not numbered) state they read in the "Voyage of Captain Franklin on the Border of the Polar Sea," that the Hudson squirrel is possessed of the singular anomaly of seeking shelter between the roots of the pine, instead of making its habitation in the tops of trees as do other squirrels.

The squirrel, I believe, seeks refuge in the underground nests for I have noted that squirrels started on the ground will often go up into the trees, escape through their arboreal highways and at a distance of one hundred yards or so descend again to the ground. Murie ('27, p. 38) remarks that "Generally, when I came upon a squirrel in winter, it took refuge in the ground," and Richardson

('29, p. 187) states that "When pursued and harassed it makes great leaps from tree to tree, but as soon as it observes the way clear it descends to the ground and seeks shelter in its burrow."

An underground nest which I uncovered July 13, 1926, in a spruce stand at Long Lake, New York, occupied a cavity continuous with an elaborate system of tunnels. The chamber was nine inches long and four inches in diameter. Its roof was twelve inches from the surface of the ground but only four inches from a side entrance in the slope under which it lay. This nest cavity was a blind pocket, approached from three angles, two of which led directly from outside entrances at slightly lower levels while the third led out into the catacombs. The nest completely filled the cavity. It had an outer layer composed of the dry leaves of maple and birch, while inside, like the arboreal nests in the same region, it was lined with finely shredded bark of the yellow birch.

A nest under the stem of an arbor vitae (Fig. 31H) was found September 4, 1926, on Valcour Island, Lake Champlain. Here the cavity, nine inches in diameter and five inches deep, was also part of an extensive series of burrows and storage chambers. Two entrances from the ground surface led into the cavity, and two from the burrows. The nest itself had but two doors. It was lined with the shredded inner bark of arbor vitae, outside which was a layer of large dry leaves. One flea was found in the nest, but no débris or excreta. The nest appeared to be in use.

A nest was discovered near Speculator, New York, June 22, when I saw an adult red squirrel rush out from a hole in the side of a decaying stump. The stump was in a stand of balsam, hemlock and birch. In an area twenty feet square about the nest there were many other tunnels and storage pits. This stump, which stood four feet high and measured two feet in diameter, was tunneled throughout. The principal tunnel to the nest had exit through a hole on the side of the stump, after a winding course of about two feet. Another led from the bottom of the nest to a blind end close to the surface of the ground, seven feet away. The nest cavity was eight inches in diameter and completely filled by a nest of leaves and shredded birch bark. Although the surrounding wood was extremely soft and wet the nest was warm and dry. There was no refuse in the nest. Another similar nest was found in a stump one hundred yards distant.

On Valcour Island two nests were found in the interstices between the logs in old piles of well rotted poplar cut into three-foot lengths. One of these nests, which were similarly located and similarly constructed (Fig. 30), was in a stand of mature arbor vitae mixed with balsam, pines, birch, oaks, and aspen. The nest was about one foot from the ground and approximately in the center of the pile. As in other nests, the outer coat of dry leaves was concentrically built up to form a layer fairly impervious to rain. The lining was of green moss and the shredded inner bark of arbor vitae. The chamber was of a size to accommodate two adult squirrels. There was no refuse or excrement in the nest.

Nests in edifices. Red squirrel nests in bird houses, attics, steeples, bridges and observatories were listed from New York by Mearns ('98a, p. 339). Audubon and Bachman ('49, p. 128) wrote that the red squirrel built its nest

occasionally in farm buildings, and that one such nest was reconstructed several times after being repeatedly destroyed. Merriam ('84, p. 210) writes of one between the ceiling and the roof of a woodshed. I have known a similarly located nest occupied the year around near Philadelphia. Murie ('27, p. 38) writes that "Occasionally a nest is built in an abandoned cabin. One such globular mass of grass, lined with caribou hair, was placed in a corner of a bunk in a cabin on the Chena River." Buller ('20, p. 358) writes of red squirrels breaking into a house in winter and making two nests in the mattresses. Here too they stored cones and fungi.

SQUIRREL "SIGN"

Excreta. The excreta (Fig. 5) of the red squirrel, which, as in most arboreal animals, are dropped promiscuously, are oval or cylindrical, free or attached, in color olive, brown or black, show no spiral twist, and are from 3 to 5 mm long by 1 to 1.75 mm in thickness. The specific character of the food material is not discernible. Feces may commonly be seen on logs where a squirrel has recently been feeding.

Tracks. The tracks of the red squirrel are rarely seen in summer because it ventures into few places where tracks would be left. In the winter, however, it leaves its tracks and their record quite clearly on the snow. The marks of both feet are then almost always paired, strictly so in short jumps, less so in the longer leaps. The fore feet strike the ground first, the hind feet following and striking usually at a point in front of the fore feet. In the shortest leaps, however, the marks of the fore feet are in front of those of the hind pair as previously stated.

Foot marks. The foot impressions are fully plantigrade, and the marks of each toe and claw often show distinctly. The size of the tracks of the red squirrel will serve to distinguish them from those of other species of squirrels living in the same area. As the squirrel usually leaps over the snow, particularly if the snow is soft, there are few tracks showing an ambulatory gait. The trail of a red squirrel usually leads from the base of one tree to that of another, to a snow tunnel or to some pocket of buried stores.

Burrows and runways. The burrows of the red squirrel may vary from an extensive labyrinth containing a nest and various store rooms, to little pits used only for the storage of food. An example of the more complex type (Fig. 31) was found on Valcour Island, September 4, 1926. The nest in this burrow has been described elsewhere in this paper. This system of works was in use at the time, as attested by freshly stored cones, the condition of the nest, which was in good repair and quite dry, and by the scolding of two squirrels during my examination of it. The burrow was located in an arbor vitae stand, in which were also a few balsam and birch trees. The forest floor was practically barren of green plants. No other diggings were located within fifty feet of this group.

The runways were in general uniform in diameter. Cavity C measured four inches high at the center; Cavity E, three and one-half inches; Cavity G, nine inches. Cavities not under a stump or a tree had earthen roofs reinforced by roots. No roof exceeded three inches in thickness. None of the tunnels was

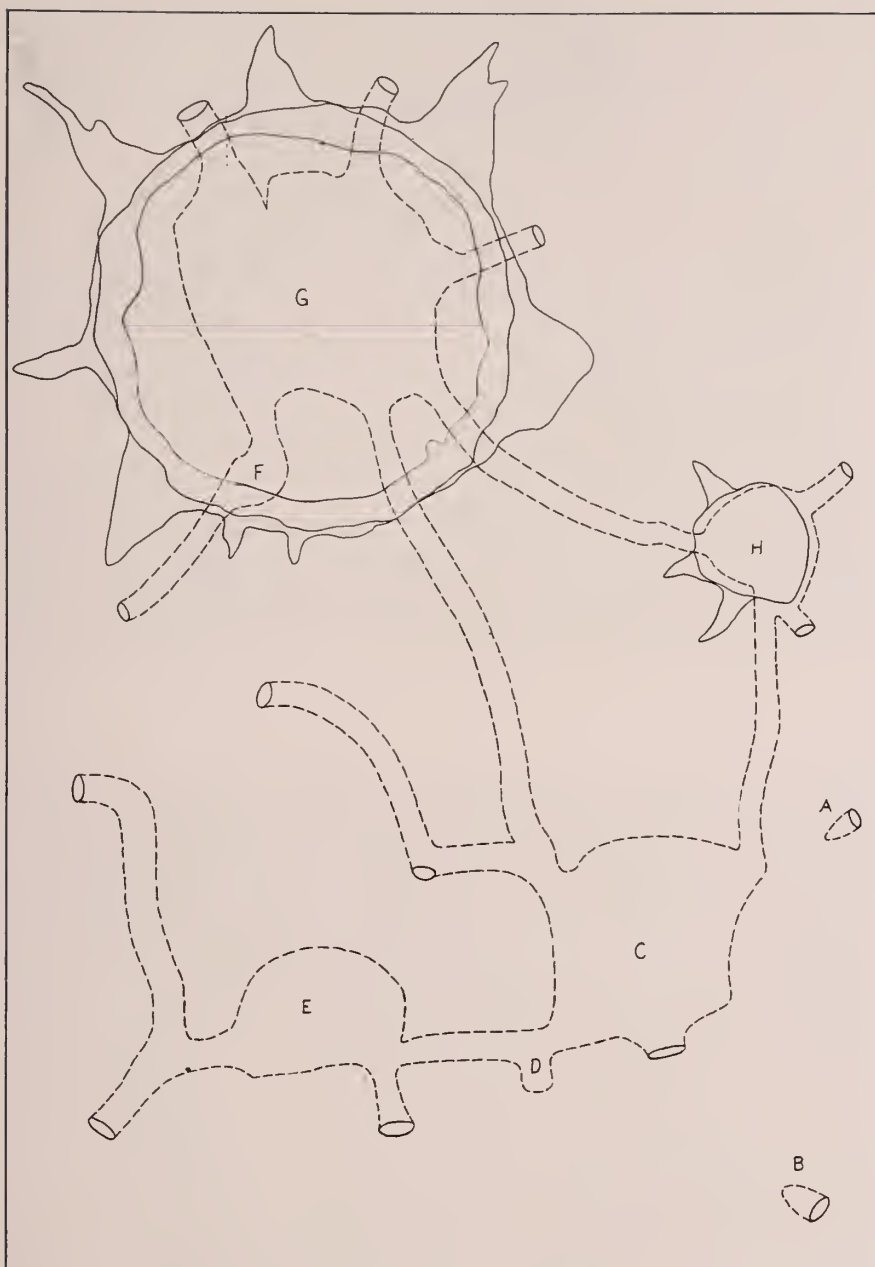


Fig. 31. Ground plan of the underground galleries of a red squirrel. Valcour Island, Lake Champlain, September 4, 1926. Key: A, B, small pockets containing balsam cones; C, D, E, chambers containing many balsam cones; F, sphere of stored sphagnum; G, large empty cavity beneath stump; H, nest cavity under living tree.



Fig. 32. Hummock in a red spruce stand, honey-combed by red squirrels and used extensively as a feeding site. T-Lake, Piseco, N. Y. July 3, 1926.



Fig. 33. Entrance to a red squirrel burrow in a feeding midden at the foot of a spruce. Long Lake. July 25, 1926.

more than eight inches below the surface. Rock was nowhere encountered. The nest occupied the hollows under the arbor vitae (H). A quart of partly green and damp bog moss was stored in a small cavity under the stump (F). A total of 117 balsam cones was packed in five of the chambers (A, B, C, D, E), 98 of which were packed in the floor and pushed into the sides of Chamber C. The large chamber (G), under the rotting stump, was apparently merely a playroom. No food litter or excrement occurred in any of the tunnels or rooms.

A series of burrows in the vicinity of a nest located in a stump at Speculator, New York, on June 22, had no stored food in walls or floor and no middens, except a few scattered scales of spruce cones. Here the soil was moist and sandy. The burrows were limited to short runways under three adjacent rotten stumps and an old log.

A red squirrel's burrow at Piseco, New York, extended for a distance of fifteen feet among the roots of a balsam. Three entrances led to this burrow, two of which were partly concealed by forest litter. As was common in the region of Piseco, one of the passages led through a hollow root, one whose center had rotted while the exterior remained resinous. In this burrow was no nest or nest cavity, nor stored food, nor any débris except some spruce cone fragments within a few inches of one entrance.

A burrow at Long Lake, New York, was like the last, except that part of the tunnel penetrated twenty-eight inches below the surface. Débris of spruce cones was common throughout the runways, and five old decayed spruce cones were found in one pocket. At Lake Placid a burrow found on August 13 contained some freshly cut coarse grass and some sphagnum, lying at its entrance. It appeared that the squirrel had had difficulty in getting the material into its burrow and had left it in the doorway. No nest was found in the cavities of this burrow. On Valcour Island, runways in a pile of rotten cordwood, in which I found no nest, contained about three quarts of litter from arbor vitae cones on which the squirrels had fed. At Piseco I found a similar pile of wood, but this appeared to have been used only in winter and contained a maze of spruce littered runways.

Walton ('03, pp. 84-85) mentions the construction of a cavity beneath a pine by two squirrels working together. The digging, performed in the hazelnut season [early September?], occupied three days.

Snow trails and tunnels. When snow falls the squirrel relies largely upon his buried stores for food and to reach these must burrow through the snow. Such tunnels may be short shafts to some pocket of food, but more commonly are extensive, interlacing networks connecting one storehouse with another and distributed apparently so as to facilitate searching for food on the surface of the ground; but the tunnels may also merely lead from one tree to another, or be random passages, probably used only for purposes of play.

Dice ('21, p. 26) writes of trails worn in the snow connecting various trees, and snow tunnels used for the same purpose. Klugh ('18, p. 10) illustrates snow tunnels in his yard where their course was determined by fences and walls. The purpose of the tunnels was to gain access to the keys of a sugar maple, which were thickly scattered over the ground. These were usually carried to one of the

exits where they were eaten. Cram ('99, p. 208) describes the snow tunnels as perpendicular shafts or radiating horizontal tunnels along which the squirrels laboriously drag the cones. Seton ('09, p. 330) describes a labyrinthine playground in a snow drift twenty feet long and six feet wide. Around the ten entrances were found remains of nuts and pine cones. Two captive squirrels of mine maintained a system of runways and chambers in the snow which drifted into their cage. They carried food in from the outside to eat in one of the large rooms in the snow. Klugh ('27, p. 13) states that "in digging these tunnels, the squirrel does not bring any snow to the surface but packs it against the walls, and makes a shaft to the surface either at the end of a tunnel, or where two tunnels connect." Fisher ('96, p. 197) notes that in nut groves extensive runways are formed under the snow in the search for food.

HEALTH AND DISEASE

Cleanliness. The chickaree is usually immaculately clean, as the result of the frequency with which it dresses its fur. After its task of digging up buried stores from moist black earth, a certain squirrel which I observed had got its face particularly dirty and looked quite ridiculous. But immediately after digging or cone gathering, the squirrel sets about washing itself and soon its fur is sleek and clean as usual.

In the season when the squirrels were busy cutting white pine cones I shot a squirrel at Petersham, Massachusetts, that had pitch in the fur of its arms and face. A similar observation is recorded from Northern Michigan, under date of August 13, by Dice and Sherman ('22, p. 37), and in this instance the squirrel had much pitch on the fur around its mouth. Klugh ('27, p. 23) states that the red squirrel thoroughly licks its fore paws and repeatedly rubs them over its nose after eating anything sticky or greasy. He, too, observes that the squirrel not infrequently combs its tail, sitting up and bringing it forward between its hind legs and running the hair through its teeth. He has also observed that the animal often rubs its lower jaw and its throat along a limb, reminding him of the actions of a cat.

Sanitation. The red squirrel, like most of the arboreal mammals, drops its dung wherever it chances to be. Feces may even be found within the nest, though not commonly. Squirrels which I have held captive would defecate in their nests, on the floor, on their food and even in their drinking water. One frequently finds their pellets on logs where they have recently fed. Seton ('09, p. 334) records an instance where a nest box once occupied by red squirrels was deserted because it had become crammed to the roof with their dung pellets, leaving no room for the nest. Klugh ('27, p. 7) mentions the case of a pet squirrel which habitually used one corner of its cage for the voiding of its excrement.

Sunning. "In the winter and early spring," writes Klugh ('27, p. 10), "the red squirrel often selects a more or less sheltered spot and basks in the sun, sometimes for an hour or more at a stretch." To this I may add that I have frequently seen them also throughout the summer spend long periods of the day basking in the sun. They will usually select a branch receiving full

sunlight, or a fence near a tree, for this purpose. Their position is then usually prone, with tail held flat over the back or stretched out directly behind.

Disease and medication. Klugh ('27, p. 8) quotes Charles Macnamara as telling him of a captive red squirrel from the back of which "one winter all the hair came off . . . from neck to tail, exposing his livid blue skin. I rubbed a little vaseline on him, but hesitated to apply any remedy as like all animals, and some primitive peoples, his sole idea of therapeutics was to lick the place, and I was afraid of poisoning him. But after some months the hair grew in again as thick and healthy as ever."

Parasites. I have found no internal parasites in the red squirrel, but I have searched only about twenty specimens for them. Hall ('16, p. 230) lists trematodes of many genera from other species of *Sciurus*, and it would seem most probable that the red squirrel, too, is subject to similar infestation.

With regard to external parasites, the chickaree is usually infested with fleas. Even the busiest red squirrel is seen occasionally to stop and vigorously scratch itself. As a general thing I have found the young squirrels more heavily infested in this way than were the adults. Occasionally, however, no fleas at all will be found on a freshly killed adult, whereas a young squirrel from the same stand of trees may have a swarm of fleas on its body. I have also, as before remarked, found fleas in the arboreal nests of the red squirrel. Fleas taken from red squirrels in the Adirondacks, and on Valcour Island, Lake Champlain, between July 16 and September 10, were of the following species; *Ceratophyllus wickhami* Baker, on eight squirrels; *C. vison* Baker, on six; and *Ctenophthalmus pseudogyrtus* Baker, on one. Three of the squirrels each carried two species of fleas.

Larval botfly infestation of red squirrels is recorded by Seton ('09, p. 332) who quotes W. R. Hine as saying that he had seen them in the scrotum of squirrels from near London, Ontario, and from the vicinity of Winnipeg, Manitoba.

In their paper on the relation of rodents to spotted fever, in the Bitter Root Valley, Henshaw and Birdseye ('11, p. 11) state, regarding *Sciurus hudsonicus richardsoni*, that "Most of those secured in good tick country were found to be infested with nymphal or seed ticks, several dozen seeds being taken from one squirrel. Most of these ticks were *Dermacentor venustus*, but several seeds and nymphs belonged to the genus *Ixodes*. Pine squirrels sometimes enter camps and houses and might carry ticks with them." Neveu-Lemaire ('27, p. 173) supposedly following Henshaw and Birdseye, list *Dermacentor andersoni* as the tick carrying *Rickettsia rickettsi*. Dice and Sherman ('22, p. 38) write of a red squirrel taken July 1, in Northern Michigan, infested with small patches of red seed ticks around the anus, on the belly anterior to the genital opening, on the thigh and at the base of one ear.

Two unidentified adult ticks were taken from the head of an adult squirrel which I shot July 25, at Long Lake, New York.

I found dense conspicuous clusters of tiny orange colored mites of the genus *Thrombicula* on many squirrels during late July, in the vicinity of Long Lake, New York. These clusters occurred about the pinna, the external auditory meatus, the external genitalia of a female, and the nipples. Mites of the genus

Hacmogamasus were found in a red squirrel's nest at Long Lake, on July 25. Nests probably serve an important rôle in the dispersal of all external parasites of the squirrel.

Longevity. Klugh ('27, p. 8) quotes an account of a pet red squirrel, furnished him by Charles Macnamara as follows: "Up to his fifth or sixth year his activity was as great as ever. Then he began to show signs of age. In his youth he used to leap straight into the door of his bedroom; later I set a branch diagonally from a lower corner of the cage up to the door, and for a long time he could climb this nimbly enough. As his infirmities increased he gave up his circling exercise and at last I had to replace the branch with a flat board with grooves cut across it, up which he used to hobble to bed. The direct cause of his death I think was lead poisoning contracted from some freshly painted furniture which was placed near his cage to dry. He may have reached out and licked the paint or perhaps the fumes were enough to kill him in his decrepitude. As well as I can remember he was in his ninth year when he died."

The record of a free though tame squirrel, known well to Walton ('03, p. 97), extends over a period of ten years.

Mortality. Old age is probably a frequent indirect (but perhaps less often a direct) cause of death among red squirrels for with the infirmities of age come a decline in leaping powers, resulting doubtless in occasional if not frequent serious falls; and there is also the declining ability to escape from enemies, and the lessening resistance to disease, cold, hunger and other vicissitudes of squirrel life.

Fear, too, has by some writers been considered a contributing factor in squirrel mortality, for a terror stricken squirrel may be too paralyzed to escape a pursuer; and even though it should be able to dash away, a reckless leap in its desperation might easily cost its life. The loss of its tail is considered by Seton ('09, pp. 317-318) a common cause of the inability of the red squirrel successfully to cope with its environment.

The known enemies of the red squirrel have been considered in this paper under the division dealing with its relation to certain other vertebrates. These foes, which will merely be mentioned here, are: large fish, rattlesnakes, black-snakes, marsh hawks, goshawks, red-tailed hawks, red-shouldered hawks, broad-winged hawks, Cooper's hawks, sparrow hawks, barred, great horned and some of the other smaller owls, and marten, fisher, mink, lynx, wild cat and the domestic cat.

Famine must result in the diminution of squirrel populations, frequently and seriously. If the red squirrel, even with its diverse food habits, cannot lay up a sufficient store of food to carry it through the winter it may die of starvation directly, or succumb in its struggle with other factors in its environment, as the indirect result of its decreased vigor.

Forest fires may locally entirely destroy not only the food and shelter of squirrels but the squirrels themselves. In this country about 8,000,000 acres are burned annually by approximately 52,000 fires. Of this total, probably over half the acreage is occupied by the red squirrel or the pine squirrel (a Pacific Slope form.) Brush

fires constitute but 3.7 per cent of the total, according to Mills ('24, p. 636). "I have never seen squirrels drift in front of a forest fire," writes Brown ('23, p. 196), "they invariably take refuge in a tree. If the fire is a light ground fire these animals escape destruction and later migrate to unburned areas. If the fire is a bad one they are either burned or else suffocated. The intense heat sears their lungs and the smoke chokes them so that they die even if untouched by flames."

If a squirrel does live through a fire, its food—including probably most of its buried stores, too—being destroyed, it must move to unburned territory, which already may be supporting its maximum squirrel population.

In 1903 a heavy fire burned the Adirondack forest between Wood's Farm and Mt. McIntyre and Mt. Colden. For three weeks this fire burned, precluding the possibility of escape for any squirrels in the central part of the area. Twenty-three years later I found this area grown up principally to aspen and birch, trees not in themselves supporting a squirrel population. Where spruces are now growing from wind blown seed or possibly from the stores buried by the squirrels before the fire, the animals are again coming back to claim their own.

Diseases of the wild red squirrel appear to be unknown. Its reported cycles of decrease may be occasioned by other factors. In an adult female taken July 19, 1926, at Long Lake, New York, I found the caudal surface of the right lobe of the liver to be a deep bluish black; but I could find no parasites in the liver nor in the gall bladder.

Other causes of death of unknown extent among red squirrels are the automobile, by which I have found a number killed on highways; possibly fighting among the males during the mating season; occasional seizure of swimming squirrels by snapping turtles and larger fishes; drowning of individuals during their rather common crossings of streams, ponds or lakes; and excessive development of the incisor teeth, which in some individuals, as reported by Emmons ('40, p. 68), must eventually lead to starvation.

It is also a common experience that, as mentioned by Grinnell and Storer ('24, p. 209), the chickaree gets caught in traps set for coyotes, badgers, martens, and other carnivores. They also record one caught in a trap set for mink, that was baited with fish entrails, and some caught in unbaited traps set out of sight in burrows of *Aplodontia* or the mountain beaver. In these latter instances the squirrels may have been on their way to drinking places. I have myself caught them in traps set for raccoon, skunk, and mink.

One of the worst enemies of the red squirrel in regions of farms and villages are men and boys, who with gun and steel and box traps on one pretext or another often wage a relentless war on it.

Indian boys were reported by Richardson ('29, p. 188) as killing many red squirrels with bow and arrow and with snares.

Following death in this squirrel I have sometimes noted a twitching of the vibrissae lasting for several minutes.

HIBERNATION

I do not know that anyone has ever found a hibernating red squirrel, though Dice ('21, p. 26) writes with reference to Interior Alaska that, "when the temperature drops below—30° F. very few squirrels are active, and they become dormant,

at lower temperatures." Nelson ('87, p. 281), however, also with regard to Alaska, writes that the most intense cold of the northern winter does not keep the squirrels in their nests more than a day or two at a time; and Murie ('27, p. 37) likewise declares that the Alaskan red squirrel does not hibernate. Seton ('09, pp. 328-329), regarding the region about Carberry, Manitoba, states that he saw them abroad during very cold weather throughout the winter, even when the thermometer registered -35° F. Klugh ('18, p. 10) says of a red squirrel he kept under daily observation in Ontario, that "It was out every day in the winter except in very stormy weather. At such times it would not appear for two or three days at a time."

PERIODS OF ACTIVITY AND INACTIVITY

The red squirrel is usually more or less active throughout the period of daylight. During the summer months I have heard squirrels calling in the woods before sunrise. At this early hour, too, my captives were most occupied in feeding and in fighting. Klugh ('27, p. 9), however, writes that two squirrels under his observation did not appear around the tree in which their food was stored until well after daylight. In the forest, during the hottest weather, there seemed to be a temporary decrease in activity about midday. My captives fed mostly about 5:00 a. m., again at 3:00 p. m., and sometimes about 7:00 p. m.

The red squirrel may on occasion be active during the night. Two captives of mine fought between midnight and 2:00 a. m., several times during one summer. Merriam ('84, p. 210) writes that the red squirrel "may sometimes be discovered in the darkest hours of the night, stealing softly over the ground—bent, doubtless, on some errand of dubious propriety. Moonlight evenings he is often active though not so noisy as during the day, and in early autumn vies with the flying squirrel in nocturnal nut husking exploits." Middleton ('23, p. 217) shows a flashlight photograph of a red squirrel pulling at a walnut used as bait for an automatic flash camera.

On Cape Ann, Massachusetts, after a period of intensive gunning, the red squirrels of the region became very wild, according to Walton ('03, p. 96), who writes that the red squirrel "has turned day into night and now harvests his nut crop in the night time. I sleep in the open air and during the harvest season I listen for hours to the sound of dropping nuts which the industrious, but wary, squirrels, are cutting from the oak trees around my cabin." Seton ('28, pp. 142-143) gives several instances of nocturnal activity.

Rest and sleep. In addition to its usual periods of inactivity during the night and in periods of coldest weather, the squirrel will cease its activities for a varying period of the day also, to rest or sleep. In harmony with my own observations Klugh ('27, pp. 9-10) states that the squirrels he watched in spring, summer and winter stopped each day for a midday rest, usually between 1:30 and 3:00 o'clock. He further describes and illustrates with admirable photographs the usual resting positions of the red squirrel: stretched out along a limb with head and tail directly extended; standing with chin resting on the limb and tail curled over the back, or, when sitting in a fork, with the front of its head resting on the limb. Cram

('01, p. 201) writes of seeing a red squirrel, fast asleep, curled up comfortably in a robin's nest.

Dice and Sherman ('22, p. 38) write of a young wild red squirrel which after eating allowed itself to be picked up. "It seemed very sleepy and slept for about half an hour before running away." "After resting," writes Klugh ('27, p. 10), "the squirrel almost invariably stretches first one hind leg and then the other, and yawns widely, curling the tongue upwards like a dog."

SQUIRREL BEHAVIOR

A more striking difference exists between the psychic traits of the red squirrel and the other diurnal tree squirrels living within its range than is suggested in their physiognomies. The red squirrel is characterized by its noisy vivacity, an impetuous inquisitiveness and a sense of ownership which is pugnaciously maintained. The chickaree's property instinct has been developed at the expense of social tendencies and manifestations of community interest, but bravery and self-reliance have been its rewards.

The red squirrel presents a psychological problem of no small interest, but not one to be easily or quickly worked out. With our present anthropomorphic methods of psycho-analysis it is at present impossible fully to ascertain the mental status of the species. Many of its actions are incomprehensible to us and nearly all are subject to multiple interpretations. Thus the vocal medley so often accompanying excitement has by many writers been considered a form of merriment. Burroughs ('01, p. 9) wrote of it: "The appearance of anything unusual, if after contemplating it a moment, he concludes it not dangerous, excites his unbounded mirth and ridicule, and he snickers and chatters, hardly able to contain himself; now darting up the trunk of a tree and squealing in derision, then hopping into position on a limb and dancing to the music of his own cackle, and all for your special benefit."

No better conclusion can be advanced than that of Seton ('09, p. 335) who writes: "The rodents are very low in the scale of intelligence, but the red squirrel ranks high in its class. It is gifted with a burning curiosity, which, tempered by prudence and aided by agility, is an excellent start on the road to knowledge."

Individuality. The more diverse the activities of a mammal, the more diverse are the traits of the individual. The red squirrel is no exception, and individuals may, after a short acquaintance, be recognized by their various characteristic attitudes, motions or mannerisms, and on longer acquaintance even many points in the animal's psychic reactions will serve to distinguish different individuals. Such individuality is illustrated in the following incident: One day in the middle of July my companion and I saw two squirrels in a tree. One of these on perceiving us, became greatly excited and ran up and down the tree, twitching and jerking in characteristic nervousness. The other squirrel, with its tail flat upon its back, crouched close against a limb, watching intently our every move, yet not itself betraying the slightest movement though we approached to within a few feet. Clapping our hands caused this squirrel to move to a higher limb where, without losing its composure, it assumed again its former position. A third squirrel was disturbed, which was ground feeding a few feet from the other two.

It bounded onto a nearby log, stopped ten feet further on, and quickly resumed feeding.

Klugh ('27, p. 28), writing of food preferences of a single squirrel observed by J. G. Needham, states that this animal was the only one in the group about the property which fed on terminal buds of spruce.

Among my captive squirrels I have found marked differences between the nervous states of a pair, the male usually being far more excitable, and subject to fits of panic.

Sociability. The red squirrel is not gregarious to the extent of cooperating in the work of a community. The necessity for laying up stores for the winter has developed a sense of ownership and independence in the species which makes it a solitary creature throughout most of the year. Yet individuals may engage in the social pastime of calling back and forth when at work. At times too the attachment between mates is binding. As I have recorded elsewhere, red squirrels are occasionally seen in groups, playing together. Seton writes ('09, p. 312): "Red squirrels will play together, chasing each other among the trees, but I never saw two of them unite to defeat an enemy or to undertake some work too heavy for single effort. One may give the alarm call on finding a lurking foe, but it seems to utter it as a menace to the foe, not as a warning to its friends. I have, I believe, seen both parents (near Toronto) gathering cedar bark for the nest."

Ownership. The sense of ownership in the chickaree seems to be well developed, not only with regard to its food stores, but even in regard to a given territory, as the quotations from Walton given further on suggest.

A feeling akin to ownership may lie in the mind of the male for his mate, for Seton ('09, p. 314) has observed a male driving away a rival from a female, outside of the breeding season.

When one squirrel attempts to steal from or even comes near the stores of another squirrel, the owner may take it upon himself to protect his property with all spirit. Walton ('03, pp. 77-78) writes: "Bismarck [a known squirrel] . . . held my door yard for several years. One winter, when there was a famine in the land because the nut crop had failed, a muscular young red thought he could drive Bismarck away. A fierce battle was the consequence, and Bismarck killed his antagonist, but was disfigured for life by the loss of the end of his tail. While Bismarck reigned, the only squirrel that gained a foothold in the door yard without his consent was his wife. He chased her away time after time, but . . . she persisted and won the day. Bismarck gave in when, instead of running away, his wife adopted the plan of running spirally up and down the tree trunks . . . It was two weeks before Bismarck would allow his mate to remain in the door yard. When peace was declared the two would eat side by side, but with Bismarck always scolding and growling, while his wife discreetly remained silent." Further, Walton (op. cit., pp. 237-238) writes of "Tiny," the son of "Bismarck," as having been allotted by his father the door yard that had been the territory of the older squirrel. Walton observed that Tiny raced his brothers, sisters, father and mother as well as strangers from the door yard and fiercely attacked any squirrel that did not depart after the first warning, which was a long drawn out chirr-r-r-r.

As I have quoted in the section on the relations of the red squirrel to other species, Walton's squirrels drove away birds and gray squirrels as well as other reds. In summary, Walton writes (*op. cit.*, p. 76), "The red squirrel owns and controls trees that bear nuts or cones and other reds respect his rights and do not invade his territory unless there is a famine."

Klugh ('27, pp. 26 and 28-29) wrote that two red squirrels which made the maple in his garden their headquarters, drove away other squirrels that came into it as well as birds which fed from their stores. One squirrel, intruding when the owners were away, choked because it tried to eat too hurriedly some pieces of meat stored there.

When a red squirrel is placed in a cage it seems to develop rapidly the sense of proprietorship, for it will invariably take the offensive when another squirrel is introduced, even though but a day later.

"Ownership of an article," writes Klugh (*op. cit.*, p. 29), "seems to be marked upon it by the squirrel licking it, and by its moving it from the place in which it is found. I have noticed again and again that when a squirrel finds something for the first time it licks it, but when it takes out something which it has had in temporary storage it does not do so, and that a thing when found *must* be moved, even though it is moved only a foot, or sometimes even six inches, and the movement does not result in a better storage place." Seton ('09, p. 325) has observed fox squirrels licking peanuts before burying them; and I have seen red squirrels licking balsam cones before feeding from them, but I interpreted their action as one of cleaning.

Pugnacity. As noted, the chickaree is aggressive in defending his proprietary rights, and, as is true with other animals, the intruder usually flees before the attack. Early in September I have found the wild red squirrels uncommonly busy in pursuing one another among the trees and over the forest floor. Several such chases which I observed led over a fairly straight course and ended by the pursuer returning alone. At this time of year the adult population is probably at its height and many new squirrels are in search of new territory. It is then that the owner must fight for his rights.

The first member of a pair of red squirrels which I placed in a cage together for two days, aggressively fought the second member, though the injuries inflicted only stiffened temporarily one elbow of the attacked. After this the second squirrel was tolerated in the nest box, but was always forced to keep away from the floor of the cage while the other was feeding.

The seriousness of the fighting is attested by Nelson ('18, p. 455) who writes: "I have seen the victim go up and down tree after tree shrieking in fear and agony and leaving a trail of blood on the snow as he tried to escape the truculent pursuer."

Fearlessness. At a safe distance in a tree the squirrel is a very brave animal in his attitude towards a creature that climbs poorly, but on the ground he displays a nervousness that is expressed in his caution, his hurried movements, and occasional whimpering as he moves. Given a sense of security the animal loses caution and becomes on the contrary quite aggressive. His excitement

mounts and he starts to scold. Becoming more and more excited, he jumps up and down, stamping with his hind feet, and jerking his tail synchronously with his barking. He may rush down the tree as if to attack the intruder, and then, no doubt in a burst of fear, rush madly back again and chatter still more excitedly.

If hunted for some time in a given region the red squirrels may become wary, and, instead of running at the approach of a person, may watch him quietly from a branch instead of scolding and following him.

Red squirrels sometimes chase other species of animals larger than themselves, yet this recklessness is not necessarily a test of bravery since the pursued is usually conscious of being an intruder. I have seen it written, without supporting facts, that the red squirrel is a match for even the large weasels.

Timidity or wariness. Wariness, the result doubtless of instinctive fear, prompts the squirrel to move rapidly under circumstances in which it would be at a disadvantage. Thus in traveling over the ground the squirrel moves not only rapidly, but usually in a course that takes it close to the bases of adjacent trees, which furnish escape from many enemies. If a person approaches a chickaree on the ground it usually rushes up a tree for safety. In descending a tree, even though the squirrel is making frequent hurried trips from top to bottom, it almost invariably checks itself some feet above to see if all is safe below.

But it is in caged individuals that one may best observe the signs of fear. One individual that from the moment of its capture distrusted me was at first so nervous that it shook violently and its teeth chattered. The captive jumped wildly between the sides of the cage, with an impetuosity dangerous to its safety. Occasionally alighting in a corner with some nest cotton near, it would pull this up in front of itself and hide for a few moments. Later the squirrel seized an apple in its cage with all four feet, and clinging to it, rolled over with it. Without righting itself the squirrel consumed about a third of the apple. Following its hasty gorging on fruit the squirrel quieted down somewhat.

Cats watching in front of the cages threw my squirrels into a panic which lasted long after the cats had gone. At such times these squirrels, ordinarily but moderately frightened by something strange, became violent in their attempts to break through the screening. Their motions and gyrations were speeded up to double those in ordinary fright.

An almost invariable accompaniment of fear is the release of the sphincter muscles of the bladder, and occasionally also those of the rectum. It would be of interest to know whether this trait, so common among mammals, is of protective significance in reducing the size and weight of the body, allowing the animal to escape with greater speed or through a smaller hole than would otherwise be possible. It may be that there is but a temporary paralysis of the nerve centers controlling tonicity in the sphincters, that has no evolutionary bearing.

Two captives which remained quiescent under conditions of captivity are cited by Mills ('98, pp. 61-74). He believed that they were feigning death. My own experience with captive squirrels would lead me to believe that they were merely "freezing" in a manner similar to such behavior in certain other well-known mammals. They did not act dead, at least in the sense that the opossum acts thus.

Curiosity. The red squirrel is prone to investigate any strange or moving object which may attract its attention. Should the object be another kind of animal, the squirrel comes closer and views the creature from many positions; if it is inanimate, it often smells it, licks it, and tests it with its teeth.

Memory. The present evidence suggests a phenomenal memory for locality in the red squirrel. Though many of its stores are made in chambers or ground pockets containing large quantities of stored food, much or most of its food is stored separately. In the trees it may possibly locate these stores by sight, but objects in the ground must be located largely by memory. Dice ('27, p. 55) has shown for the fox squirrel that walnuts buried in a sand tray to which a squirrel commonly came for food were never found, even though they were close to the surface, and the squirrel dug about more or less in the sand. Klugh ('27, p. 29) says: "Time after time I have seen it [a squirrel] go by the nearest route to something it has stored, take it out and eat it. I have seen it go to the ground and retrieve nuts when there was to my eyes no evidence that a nut was buried there. The most conclusive proof of the strength of its location memory was given by an incident in the winter of 1924-1925. The squirrel had buried nine nuts in the snow on the balcony one afternoon. During the night there was a heavy snowfall, and the new snow lay over a foot deep on the balcony. Next morning the squirrel came, went without hesitation to each place, dug down, and successively brought up the nine nuts. In many cases there is a possibility that the sense of smell may play a part in the finding of objects, but in the last case cited this seems to be out of the question." Walton concluded from his observations that the squirrel remembered each spot in which nuts were buried. He writes ('03, p. 79): "When he had thought out a spot he would run directly to it and conceal the food under some leaves or pine needles, and return to the door yard for more. No two nuts or bits of bread were concealed in the same place. Several times I experimented to find out how many trips Bismarck would make. The greatest number was fifty-one. While the experiment was going on I noted each hiding place, as well as I could, and afterwards saw the squirrel go to many. He certainly remembered each spot and his keen scent did the rest."

Play. One frequently sees squirrels chasing each other in turn about a tree or within a small circle. Such behavior is usually interpreted as play. I have watched halfgrown squirrels pursuing one another around the trunk of their nest tree as though they were playing "tag." Klugh ('27, p. 14) writes about a squirrel which frequently played by itself, dashing through piles of newly fallen snow in evident enjoyment. The same squirrel was observed many times to go through a remarkable performance of which Klugh says: "At the top of the trunk of the maple at the point at which the main limbs are given off there is a trough-shaped, vertical cavity some eighteen inches long with a pocket-shaped bottom. The squirrel often got in this cavity, turned over and over in a series of somersaults, sliding down the trough on its back at each backward turn. It sometimes also seized and held onto its tail and rolled about in the pocket."

Association, reflection, resourcefulness. Without entangling ourselves in discussions of instinct, it may be said that there seem to be several cases on record which amply support the writer's conviction that the red squirrel shows no little sagacity in its daily life. The squirrel's ability to anticipate and to find a solution to new conditions is documented by many incidents. Klugh ('27, pp. 29-30) cites the following cases from his own observations on one red squirrel. After chasing a nuthatch away from a piece of food stored in a tree, this squirrel bounded over to another stored piece as if anticipating an attempt by the bird to steal that also. This squirrel would hasten to guard its food whenever a nuthatch came into the tree. On one occasion, when it had discovered that the observer had returned after an absence for a few weeks, the squirrel came out upon a limb in anticipation of receiving food, as had been its habit before. On another occasion this squirrel dropped an apple peel at which it was pulling, in order to seize a whole apple which had started rolling from a projecting board on which it had been placed.

Reflection seems to be exhibited by the red squirrel in such acts as rearranging things which it has stored, and in returning to such objects a moment after they have been placed, to put them in a better position, or to store them at a different spot. Mills ('98, p. 73, quoting C. P. Girdwood) writes of a young chickaree which soon after being caged submitted to having parasites removed from its skin, voluntarily remaining quiet during the act. This animal must have been an unusual individual, for few of its species would have shown such confidence in man or recognized the benevolence of the act.

The action of a squirrel which carried each acorn that it cut in a certain tree to the south side of this tree, where it would fall to clear ground and not among the dense mass of brambles and cat briers on the north side, is described by Walton ('03, pp. 86-87). This squirrel showed intelligence in its action, though it may have been the difficulty encountered in securing the first nuts dropped on the north side of the tree which prompted the action.

The best example of resourcefulness which I have happened upon is described by Walton ('03, pp. 242-245). Walton was in the habit of placing hempseed in a shallow tray on the ground, for the birds, but chipmunks and red squirrels stole the lion's share. He writes: ". . . last fall I placed a wire netting over a shallow box, so that the birds could pick out the seeds while the squirrels could not get their noses through the mesh. The chipmunks were puzzled and one after another gave up in disgust. . . . When Tiny [a red squirrel] found the box he got mad all through. He crowded his nose against the wire netting, biting savagely meanwhile. . . . Finding that I would not help him he returned to the box. He tried the wire a short time, then sat up and folded his paws across his breast and fell into a brown study. Like a flash he came out of his trance, grasped the box and turned it completely over, then he began to eat. . . . After this, whenever he found seed in the box, he quickly turned them out. . . . Later I drove stakes across the box to hold it down. I returned one day to find that Tiny had managed to dig a hole beneath the box, and had gnawed through the bottom. . . . I stretched a cord between two trees, and half way suspended a box open at the top. Tiny saw the birds eating from the box and he quickly understood that it was another device of mine to outwit him. He ran up one of the

trees, and tried the limbs that hung over the box. He soon found a slender limb that would bend under his weight and let him into the box. After he had used this highway several days I cut the limb away. When Tiny found a fresh stub instead of a limb he understood what it meant. . . . His next move was to investigate the line where it was attached to the trees. He thought he could reach the box over the line and started out. When about a foot from the tree the line turned, and Tiny jumped to the ground. He tried this three times and met with failure. The fourth time when the line turned he clung to it and made his way to the box, hand over hand. I thought he deserved a reward for his continued effort and intelligence so since then I allow him to eat from the box whenever he feels like it."

The strategy displayed by a squirrel turned loose in front of a dog in an open field is described by Burroughs ('01, pp. 142-143). By adopting a zig-zag course and jumping back between the dog's legs he so bewildered and astonished his pursuer that he gained the safety of the trees.

Expression of mental states. In attitude and voice the squirrel may show its mental state, if one can but learn to interpret correctly its poses and sounds. In the section on voice in this paper, I have treated the vocal expressions. Klugh ('27, p. 30) has best analyzed the attitudes of the squirrel and writes that "the attitude of surprise is either one in which the animal draws itself back on its haunches and allows both fore paws to hang from the sides or else picks up first one fore paw and then the other. In fear the body is flattened, the head dropped, and the tail held straight out. In curiosity the neck is stretched out to a remarkable degree. Anger is shown by stamping the hind feet and jerking the tail; sometimes by stamping the front feet as well. Attention, especially listening, is shown by folding one paw and placing it against the breast, if the animal is on 'all fours,' or bringing both fore paws against the breast, if it is sitting up."

FOOD, FEEDING HABITS AND RELATED ACTIVITIES

The food of the red squirrel is about as diverse as the supply available in the territory that it inhabits. In the south the squirrel has a wider choice than in the extensive and often little diversified conifer forests of the north. Yet, though the life of the red squirrel is more intimately related to the cone-bearing trees than is that of any other North American squirrel, its food habits are, I believe, the most diverse. The forest trees are ever the squirrel's chief resource and because of the intimate relation existing between this animal and the forest its food habits deserve careful study.

Every tree species within the red squirrel's range is probably used by it to some extent, either as a source of food, or of nesting material. A check of the trees of New York State has shown that the species of which I have no record as serving the red squirrel in either of these ways are of southern distribution and share little territory in common with the chickaree, or that the species are, like the oaks, the hickories and the willows, not clearly differentiated in the minds of most untrained observers. There now follows an annotated list of the trees, shrubs, fungi and other vegetable matter known to enter into the dietary of the red squirrel, and a consideration also of its animal food.

ANNOTATED LIST OF FOREST TREES, SHRUBS AND OTHER
SOURCES OF SQUIRREL FOOD

TREES

White Pine (*Pinus Strobus*). The red squirrel feeds upon the seeds of the white pine and may construct its nest among its branches. The seeds are first eaten in late summer, when the cones have attained a growth of about fifteen months. The cones are then green, though practically full sized. Cram ('99, p. 206) states that the harvest begins as early as late July. In the Harvard Forest I found no fresh cuttings until mid-August; but from then on the cones are harvested until they become dry and drop their seeds. They are stored away and evidently furnish food throughout the ensuing twelve months.

In those parts of the range of the red squirrel where the white pine occurs its seeds appear to be one of the most favored items in its diet.

The first week of September a pair of squirrels which I held captive, while I was in the Harvard Forest, consumed the seeds of four hundred and twenty-two second-year pine cones. A total of five hundred and seventy-five cones was placed in the cage during this period. The greatest number used in one day was eighty-six, there being one hundred and twenty-five cones in the cage at one time.

The only other food supplied them in this period was apples, of which they ate three.

The cones consumed by the pair of captive squirrels in seven days feeding represented approximately the total crop of two fifty year old trees during the summer of 1925. In the free state the squirrels at this time of year fed on large quantities of mushrooms, hazelnuts and other foods, as well as on white pine seeds. It seems then unlikely that a pair of squirrels free in the forest would at this time of year consume quite so large a quantity of pine seeds as did the captives, though they might cut an even larger number of cones for future use. Thoreau ('06, p. 196) says: ". . . I think that I may venture to say that every white pine cone that falls to the earth naturally in this town before opening and losing the seeds . . . is cut by a squirrel, and they begin to pluck them long before they are ripe, so that when the crop of white pine cones is a small one, as it commonly is, they cut off thus almost every one of these before it fairly ripens." According to Cram ('99, p. 205), "The white pine is usually rather sparing in its yield; but once in every ten or fifteen years, perhaps oftener, nearly every tree in the forest bears enormously, even the younger ones showing scattered clusters here and there, while those that have stood for generations present a roughened, shaggy aspect from the thickly crowded cones at their summits. At such times the red squirrels seem determined to gather every cone before it opens and scatters its seeds to the wind."

Over much of New England the white pine is at present the only important lumber tree, and in these regions it is fast succumbing to the attacks of insect pests and disease. Directly affecting the production of a new generation of seedlings there are two factors operating adversely, the cone borers and the red squirrel. In the Petersham area, during the summer of 1925, over thirty per cent of the cones examined were riddled by the cone borers. With such competition

the squirrels must eventually fall back on other food resources, find new foods, or be greatly reduced in numbers.

Pitch Pine (*Pinus rigida*). The seeds of this pine are preferred above all others except the white pine, according to Cram ('99, p. 211). Thoreau ('06, p. 196) says that almost every pitch pine cone falling in that part of New England of which he wrote was cut by red squirrels: "I have counted in one heap, within a diameter of four feet, the cores of 239 pitch pine cones which had been cut off and stripped by the red squirrel the winter previous." In areas of pitch pine the squirrel fills an important gap in the utilization of lands which are commonly meager in their vertebrate fauna, for here the carnivores may increase with the squirrels.

Jack Pine (*Pinus Banksiana*). Seton ('09, p. 323) writes that about Carberry, Manitoba, the principal autumn (and therefore winter and spring) food is the seeds of the jack pine. Spreadborough ('19, p. 61) also reports that in the Jasper Park Canadian Rockies the jack pine is a food tree, and Wood ('14, p. 94) speaks of it as one of the principal food trees on Whitefish Point, Northern Michigan.

Red Pine (*Pinus resinosa*). I have found in a midden of spruce cones, at Long Lake, New York, a single squirrel-cleaned core of a red pine cone. Captive squirrels accepted the seeds of this tree readily. The opportunity to examine a stand of this species for squirrel work has not presented itself, and I find no records in the literature of its utilization.

Scotch Pine (*Pinus sylvestris*). Seeds and winter buds of the Scotch pine furnish food to the red squirrel in some localities where this pine has been introduced. The cones are taken and used at the same time and in the same manner as are those of the white pine. In feeding on the winter buds the squirrel cuts off a bud at its base. The inner green tissues are eaten and the large papery husks drop to the snow below. A large cluster of buds caps the leader. In most cases each one of these is destroyed and the tree has no means for continuing its growth in height until a new set of buds is formed below the injured whorl. With the advent of the growing season these new buds send forth their shoots at a nearly equal rate, so that instead of a straight leader with well formed ring of laterals below, there is developed a group of competing branchlets which form a "broom" at the crown of the tree. The annual repetition of such injury, together with similar injury to the buds on branches below the leader, results in a growth resembling a bush more than a well formed tree.

In a plantation at North Ashburnham, Massachusetts, I found eighty-eight per cent of the Scotch pine deformed by terminal budding. In twenty-eight per cent of all the trees only one leader had been killed, while in forty-two per cent also a second one had been injured. Twelve per cent had been clipped three times, five per cent four times, and one per cent five times. Similar though less serious injury was observed at Petersham, Massachusetts, and Saranac Lake, New York. No injury was found in plantations examined through Bronx, Westchester and Dutchess counties of New York, and in Northern New Jersey and in Southern Connecticut. Damage is greatest in winters of heaviest snowfall.

Squirrels as a rule apparently do not build nests in the Scotch pines of plantations until the trees are about fifteen years old and bear cones.

Other pine species. Bailey ('18, p. 38) lists lodgepole pine, mountain white pine, and white-barked pine as food trees of *S. hudsonicus richardsoni* in Glacier National Park. He states that late in winter the squirrels evidently feel the need of green food for they often eat the tips from pine branches and the inner bark of the twigs just back of the tips.

Grinnell and Storer ('24, p. 208) say that *S. douglasii albolimbatus* feeds on the cones of lodgepole, Jeffery, and mountain pines.

In New York State, the two pines for which I have no records, the scrub pine (*P. virginiana*) and the short-leaved pine (*P. echinata*) are both southern species.

Larch (*Larix laricina* and *L. decidua*). The red squirrel injures European larch plantations by clipping off many slender twigs from which it later eats the buds. The twigs, from six to twelve inches long, are cut close to the trunks.

After the twig has been cut the squirrel hollows out the buds along its margin and at the tip, then drops the twig to the snow below. Only rarely are leaders cut. In consequence the stems are almost always desirably straight.

Usually the clipping of twigs from the main stem is more or less limited to a zone midway up the trunk, though in more severe cases it extends the length of the stem and reduces the tree to a nearly barren pole. A tree with a belted or irregular contour invariably shows numerous short stubs of twigs along the trunk and a mat of cut twigs at the base.

Injury by twig cutting is produced during periods of heavy snowfall. A second cycle of damage occurs in the spring when the buds show first signs of growth (Hosley, '28, p. 46), but then the buds only are removed, the twigs being left untouched.

Similar injury to native larch in Maine swamps has been reported to me. Klugh ('27, p. 16) reports seeing the squirrels feed on the staminate catkins of the larch, and Bailey ('18, p. 38) refers to the western tamarack as a food tree in Montana.

White or cat spruce (*Picea canadensis*). The red squirrel feeds on both the seeds and the winter buds of the white spruce. At North Elba, New York, I found them cutting the cones of this species on August 14, and in early September on Valcour Island, Lake Champlain, I saw them cutting and storing these cones. Preble ('08, p. 170) says that during the winter in the Athabasca-Mackenzie region the squirrels lived almost exclusively on the seeds of white spruce, and Dice ('21, p. 25) writes of the dependence of the red squirrel of Interior Alaska upon the white spruce for its food supply. Many other writers also mention the spruces as food trees, but often without designating the species.

Damage caused by winter bud feeding was common on Valcour Island. The squirrels cut the leader or the end of a lateral twig not over seven millimeters in diameter and then remove the buds. In consequence the stubs left by them are clearly marked for several years following the injury (Fig. 35). The leaders are more commonly cut than the laterals, yet all in all the trees seem to suffer



Fig. 34. Comparison of the crown of a white spruce damaged by budding by red squirrel (left) with an uninjured white spruce crown. Valcour island, Lake Champlain. August 26, 1926.



Fig. 35. Crown of young white spruce with its leader cut by a red squirrel. Valcour Island, Lake Champlain. August 26, 1926.



Fig. 36. Crowns of balsams heavy with new cones. A favorite feeding place for the red squirrels when the cones are not infested with cone borers. Long Lake. July 25, 1926.



Fig. 37. Crown of red spruce with an average crop of cones. The principal food resource of the red squirrel over a great part of its range. Long Lake. July 25, 1926.

little from this operation. One sees no crooked trunks among the local trees. For a year or two after the removal of a leader there is sometimes competition for the position by two or more laterals, but eventually one secures the lead and the tree straightens out. The damage appears to have been unusually heavy in the winters of 1922-23 and 1925-26.

Merriam ('84, p. 214) refers to the squirrels biting off the terminal twigs of spruce in order to get the little buds along its edge, but it is not clear whether he referred to white spruce, red spruce, or both.

Red Spruce (*Picea rubra*). The red squirrel feeds on red spruce as readily as on white. In the Harvard Forest I found the squirrels late in August cutting down vast quantities of green cones. Ninety such cones were placed in a cage where I had a pair of red squirrels. The squirrels worked all of the seeds from their scales, yet ate few or none of them, as was attested by the débris sifted from their cage. In the stand from which these cones came every stump was capped with a spruce cone midden (Figs. 38-39), but the scales in such piles had the bronzed color of cones which have for a time been buried. In mid-July at Long Lake, New York, the spruce cones on which the squirrels fed were also of this color. At Nick's Lake, near Old Forge, New York, I noticed, on July 8, a squirrel removing similarly colored and old looking cones from an underground pocket. Are the squirrels at this season feeding on cones they buried almost a year before?

Klugh ('27, p. 15) writes that in the typical Canadian zone in New Brunswick the squirrels feed largely on this species and on the white spruce.

Black Spruce (*Picea mariana*). In Alaska, according to Dice ('21, p. 25), the red squirrels live in forests of white spruce, and occur rarely in those of black spruce. On October 16 he observed a squirrel as it bit off and ate the buds of black spruce. Bell ('98, p. 75) on the other hand refers to the black spruce seeds as a staple food of the squirrel in the far north, both in summer and in winter.

Norway Spruce (*Picea abies*). No Norway spruce trees of cone bearing age have come under my observations in red squirrel territory, yet it may be expected that the squirrels will eat the seeds of this species also.

Serious injury by bud cropping has been done by red squirrels to plantations on the Harvard Forest in winter. The injury is primarily the result of trunk deformation rather than of defoliation. The terminal bud, which is well protected from above by a cluster of sharp needles, is usually cleaned out from the base, leaving a hollow, normal looking bud sheath. If the bud is not destroyed *in situ* the squirrel may cut off the terminal or a lateral cluster from one to four inches back from the tip, and, carrying it to a secure resting place in the same tree, will proceed to feed upon the buds. The most frequently budded parts are the leaders and the tips of the first whorl below the leader. The tree is saved from serious deformation by the vigorous perpendicular growth of one or more shoots from uninjured buds or branches below the old leader. Occasionally as in the white spruce, more than one leader is sent up and the competition is wasteful to the tree. Bending of the main stem of the tree due to the development of a new leader

from a lateral bud is not permanent, for the change in angle is not great and disappears with the annual increase in girth.

Seasons of heavy snowfall, shutting off the squirrels more effectually from their buried stores, are the periods of greatest bud destruction. Trees under four feet high in the Petersham area appear to escape injury. One plantation of older trees escaped all squirrel injury probably because of its maturity and the abundant food supply of the heavy mixed forest adjacent.

Engelmann Spruce (*Picea Engelmanni*). I have known *S. hudsonicus baileyi* to feed on Engelmann spruce seeds in Wyoming, and *S. fremonti* to eat these seeds in Colorado and Arizona. Bailey ('18, p. 38) lists the species as a food tree of *S. h. richardsoni* in Glacier National Park.

Douglas Fir (*Pseudotsuga mucronata*). This tree, which occurs as an escape here, is used as a source of food supply by the red squirrels in Westchester County, New York. In Montana, according to Bailey ('18, p. 38), and in the Canadian Rockies, according to Spreadborough ('19, p. 61), the cones of the Douglas fir are regularly cut by the squirrels of those regions.

Balsam (*Abies balsamea*). At Long Lake, New York, I found the squirrels feeding on balsam cones during the latter half of July; and during the first half of August they were feeding on these cones and cutting them extensively for storage purposes in the Lake Placid district. On Valcour Island the squirrels were similarly engaged during my observations in that region through late August and early September.

On July 27 I placed a large number of balsam cones in the cage of my captive squirrels at Long Lake. One of the squirrels worked rapidly and without interruption until all the cones were torn apart and a large litter made, yet this individual ate none of the seeds nor did it even remove them from the bracts. The cones at that season were abundant on the trees, though about eighty per cent were infested with cone borers. In fact I found few cones at Long Lake that were cut or cleaned by the red squirrels. The behavior of my captive squirrel may have been due solely to a restless activity that possessed him rather than to the desire for food. There was an abundance of other food in the cage.

The utilization of balsam seeds for food by the red squirrel is reported from Genli, Manitoba, by Klugh ('27, p. 20), from Glacier Park by Bailey ('18, p. 38), and from the Canadian Rockies by Spreadborough ('19, p. 61). The balsam cones, like those of other coniferous species, are extensively stored.

Hemlock (*Tsuga canadensis*). After the cones of these species have been harvested the squirrels, according to Cram ('99, p. 211), turn their attention to the hemlock, the cones of which hold their seeds all winter. He says further that the squirrels eat the hemlock cones as fast as gathered.

Stone and Cram ('03, p. 174) have written that "There is never a day of snow or winter sunshine that the red squirrel may not be seen gathering [hemlock cones] from the very tips of the swaying outer branches." Klugh ('27, p. 15) also states that the seeds of hemlock are eaten throughout the winter in Northeastern North America, and Walton ('03, p. 90) observed that the hemlock cones were



Fig. 38. Squirrel midden of spruce cones on a low stump. T-Lake, Piseco. July 3, 1926.



Fig. 39. A red squirrel's feeding table, in a red spruce swamp at Petersham Mass. September 10, 1925.



Fig. 40. Branches of a sugar maple, showing the manner in which bark has been spirally removed by a red squirrel. Specimens from the Roosevelt Wild Life Station. Photograph by C. E. Johnson.



Fig. 41. Red squirrel carrying food in its mouth. Yellowstone Park. Photograph by J. M. Johnson.

gathered after those of white pine and were husked at the foot of the tree in which they were gathered. Rowley ('02, p. 35) says that in Westchester County, New York, the red squirrels feed on the seeds of hemlock in cold weather. Ninety hemlock cones which I placed in the cage of a pair of squirrels at Petersham, Massachusetts, were husked in less than twenty-four hours; yet, judging from the number of large round seeds, mostly with wings attached, that sifted from the litter, I hardly think that the squirrels ate many of them. To my taste these hemlock seeds were not unpalatable.

Arbor Vitae (*Thuja occidentalis*). I am told by Henry Seton that between August 5 and September 20, 1925, he saw red squirrels in the tops of arbor vitae cutting large clusters of cones which fell to the ground of their own weight. The ground in places was said to be littered with these clusters. Professor George Hudson has told me that he believes that the squirrels on Valcour Island feed largely on arbor vitae in the winter season. On September 4, 1926, I found on this island a ground pocket from which a red squirrel had just dug out several bunches of the cones of arbor vitae stored the year before. In all, the cones loosely packed would have filled a pint measure. Nearby I found a place where a few cones had at one time been eaten. In a rotted log pile in another part of the island was a considerable mass of debris from such cones.

That arbor vitae cones may be only a famine food is suggested by the fact that I found no newly cut cones on the island between August 18 and September 12, 1927, and that the year previous had been remarkable for the degree of damage done to the buds of white spruce.

My captive squirrels were offered newly cut cones of arbor vitae, August 22, when I was on Valcour Island, but they ignored them entirely. These squirrels were, however, from a locality in the Adirondacks where the cedar was not present and thus was a tree with which they had had no experience.

Johnson ('22, p. 36) writes that the squirrels in a certain section of Northern Minnesota fed largely on the seeds of cedars in the summer months; and Klugh ('27, p. 15) says that this food is eaten extensively also in New Brunswick, Quebec and Ontario.

The arbor vitae is of further service to the red squirrel in furnishing bark for construction of its nest, as well as occasional natural cavities in which it may find shelter.

Willow (*Salix sp.*). Walton ('03, p. 92) writes that "In the spring, pussy-willow buds formed a part of Bismarck's [a red squirrel] food. I found the buds nearly tasteless, but they crunched between the teeth like a crisp cucumber." Klugh ('27, p. 16) records the chickaree as feeding on the buds of a hybrid willow (*Salix alba* x *S. fragilis*).

Quaking Aspen (*Populus tremuloides*). The thin greenish outer bark of this tree forms the third principal winter food supply of the red squirrels in Manitoba, according to Seton ('09, p. 327). He writes that the squirrels gather it as needed in times of famine. Klugh ('27, p. 16) says that in the spring he has seen squirrels feed on the buds of this aspen.

Balsam Poplar (*Populus balsamifera*). Preble ('08, p. 170) found that the squirrels in the Athabasca-Mackenzie region fed on the blossoming catkins of this tree, about the middle of May.

Butternut (*Juglans cinerea*). On September 7 and 8 I saw a squirrel carrying away butternuts from two isolated trees in the Harvard Forest and at the same time I found a newly fallen butternut that had been partly eaten by the red squirrel. My captive squirrels also ate butternuts in early September, when they were still covered with a green husk. I do not know whether the squirrels cut this mast down or whether it falls because of seasonal ripening changes.

A red squirrel near St. Thomas, Ontario, is recorded by Johnson ('18, p. 54) as storing butternuts. Also Burroughs ('01, pp. 12-13) and Klugh ('27, p. 16) include this species as red squirrel food.

Black Walnut (*Juglans nigra*). Burroughs ('01, p. 12) and Klugh ('27, p. 16) both mention this nut as a red squirrel food. Thoreau ('06, p. 198) records a hoard of one bushel and three pecks of walnuts gathered by a red squirrel family.

Mockernut (*Carya alba*). Audubon and Bachman ('49, pp. 128-129) record a large store of the nuts of this tree.

Pignut (*Carya glabra*). Thoreau ('06, pp. 190-191) writes of seeing a red squirrel bury two green pignuts with their husks on, about 1½ inches beneath the soil, the proper depth for planting. Burroughs ('01, p. 12) also speaks of watching a red squirrel harvest pignuts, but of numerous other records of hickory nuts as red squirrel food, none bear specific designation.

Hop Hornbeam (*Ostrya virginiana*). Klug ('27, p. 16) says he has seen red squirrels eat the buds of the ironwood.

Sweet Birch (*Betula lenta*). "Many times during the springtime I have seen red squirrels licking eagerly the twigs of a sweet birch (*B. lenta*) opposite my window," writes Seton ('09, p. 328). "I could not see that they got anything; they certainly were not removing the bark."

Yellow Birch (*Betula lutea*). August 9 to 11 at Lake Placid, New York, I found the squirrels busily engaged in cutting the green catkins of yellow birch and eating their contents. I watched one squirrel harvesting the catkins in the top of a thirty foot birch. Many dropped to the ground, whether accidentally or not I could not ascertain. It is hardly to be expected that the squirrels would store such foods. Since the yellow birch is a common forest tree in the Adirondacks its catkins are probably an important squirrel food throughout the region. Klugh ('27, p. 16) says that he has seen the squirrels eat birch buds in the spring, also.

Paper Birch (*Betula alba* var. *papyrifera*). August 18 to 21 I saw the squirrels on Valcour Island feeding on the catkins of this species, high in the tops of the trees. Numerous catkins on the ground below where the squirrels were operating suggested that much cutting was done before they were gathered. My captives at Lake Placid accepted the catkins as early as August 15. On July 20 they had refused them.



Fig. 42. Series of cones compared with their cores as left by the red squirrels at their feeding places. Upper row (left to right) hemlock, red spruce, white spruce; lower row, white pine, red pine, balsam.



Fig. 43. Cores of red spruce cones from red squirrel middens in the Adirondacks. The type at the left is the most common, that at the right uncommon. The intermediate type, in the center, is exceptionally rare.

Beech (*Fagus grandifolia*). Beechnuts were occasionally found in squirrel middens, throughout the part of the Adirondacks visited. Several residents of the region expressed the opinion that this mast was a staple food resource of the squirrels, and Klugh ('27, p. 16) records the squirrels eating both the mast and the spring buds of the beech.

Chestnut (*Castanea dentata*). The chestnut, before its near extermination by the blight, was an important nut tree for the red squirrel. I have a record of a squirrel eating a chestnut in the Harvard Forest, September 8, 1925. The nut had been borne by a living branch near the high top of an old chestnut that was dying. Burroughs ('01, p. 1) writes of the squirrels cutting the burrs just when they were mature and were beginning to divide, while according to Seton ('09, p. 324), in Connecticut they are cut about two weeks before they are ripe.

White Oak (*Quercus alba*). The acorns of this species are eaten by the red squirrels (Klugh, '27, p. 16).

Burr Oak (*Quercus macrocarpa*). Acorns of this species are likewise eaten (Klugh, '27, p. 16).

Red Oak (*Quercus rubra*). At Petersham, Massachusetts, on September 11, I watched a red squirrel cutting acorns from a large red oak tree, about 7:00 p. m., when nearly dark. The acorns were cut rapidly and allowed to fall to the ground. My captive squirrels ate acorns from this tree during the same week. On Valcour Island my caged squirrels ate the heart of green acorns as early as August 21. Klugh ('27, p. 16) mentions seeing the squirrels eat the staminate catkins of red oak, and Cahn ('21, p. 72) writes that in Itasca County, Minnesota, the oak trees furnish the chief item of food for the red squirrels, though no mention is made of the species.

White Elm (*Ulmus americana*). June 16 to 18 I observed a pair of red squirrels feeding in the tops of two high elm trees near Speculator, New York, cutting the clusters of seeds, and eating many but dropping great quantities of them in a seemingly very wasteful manner. One squirrel dropped seven seed clusters in ten minutes, and fed from twice as many. From each cluster the squirrel ate about one-third the seeds present. From the average dozen seeds in a cluster, then, the squirrel ate about four. Torrey ('01, p. 211) observed seed feeding May 26.

Cram ('99, p. 219) writes of the red squirrel eating the opening blossoms of elm in April, and also Klugh ('27, p. 16) states that he had seen the squirrels feed in spring on the buds of elm.

Tulip Tree (*Liriodendron tulipifera*). The seeds of this tree are eaten by red squirrels in New Jersey, according to Stone ('08, p. 84) and Donald Carter.

Pear (*Pyrus communis*). Rowley ('02, p. 35) says that in Westchester County, New York, the squirrels are very fond of the seeds of pears; and Stone ('08, p. 84) writes that they eat the pears for the seeds only, the other parts apparently being disregarded.

Apple (*Pyrus Malus*). Apples were eaten by all my captive squirrels. They would eat the entire apple, except, occasionally, the skin, even though there was a great abundance of other favored foods in the cage. Also in orchards in New York, Massachusetts, Pennsylvania and Michigan, I have watched the squirrels eat apples. Stone and Cram ('03, p. 174) write that the squirrel also stores apples where available. Walton ('03, pp. 92-93) says that "Wild apple trees abound on Cape Ann, and Bismarck attacked the fruit early in the fall. He destroyed great quantities for the seed, which was the only part stored for winter use. However, he seemed to relish an apple, if it was not too sour, and all through the winter he would eat a Baldwin apple even to the seeds, at one sitting." [!] And Burroughs ('01, p. 11) remarks: "I have seen the ground under a wild apple tree that stood near the woods completely covered with the 'chonkings' of the frozen apples, the work of the squirrels in getting at the seeds; not an apple had been left and apparently not a seed had been lost." Klugh ('27, p. 17) says that the red squirrels "take apples more frequently than any other kind of fruit, especially those that are left hanging on the trees all winter."

Thorn Apple (*Crataegus* sp.). Red haws were eaten by my captive squirrels from the Adirondacks, on August 21.

Wild Black Cherry (*Prunus scrotina*). Walton ('03, p. 89) writes of a red squirrel gathering the fruit of this tree on Cape Ann, Massachusetts.

Wild Red Cherry (*Prunus pennsylvanica*). Red squirrels in the Harvard Forest gathered the fruit of this tree when it was quite ripe, evidently for the seeds only.

Plum (*Prunus domestica*). Wild red squirrels as well as captives under my observation have eaten not only the fleshy part of prunes, but have opened the stones for their seeds.

Sugar Maple (*Acer saccharum*). This tree is among the most important food sources for the red squirrel where their ranges coincide. The squirrel feeds upon its bark, sap, buds, petioles and keys.

The bark is eaten at all seasons of the year, according to Klugh ('27, p. 16), and Burroughs ('01, p. 11) mentions that "A young bushy-topped sugar maple about forty feet high standing besides a stone fence near the woods, was attacked and more than half denuded of its bark. The object of the squirrels seemed to be to get at the soft, white, mucilaginous substance [cambium layer] between the bark and the wood. The ground was covered with fragments of the bark and the white naked stems and branches had been scraped by fine teeth."

A bundle of limbs of sugar maple is in the teaching collection of the department of zoology, New York State College of Forestry, from which a red squirrel has cut many small patches of bark, usually from one quarter of an inch to an inch in diameter. Much of the cutting was done spirally (Fig. 40). There is, too, in the collections of this department a bundle of strips of bark (No. 1318) four to six inches long, and about one-third of an inch wide. These specimens, clearly the work of the squirrel, are from Baldwinsville, New York. Notes under date of July 18, accompanying the specimen, state that the ground below the

tree was "well covered" with strips of bark and that the destruction was continuing. No other trees had been touched.

The seeds of the sugar maple are eaten in great quantities by red squirrels as well as by gray squirrels. At Speculator, New York, the middle of June, I found the ground below sugar maples, both in the forest and in shade rows along the roads, littered with the twig tips, leaves and seed clusters dropped by the red squirrels. But a small portion of the clusters dropped had been pitted. Klugh ('27, p. 16) records similar observations.

The petioles and the buds are eaten in the spring (Klugh, '27, p. 16).

The sap of the sugar maple, which is taken in such relatively great quantities, appears to be more than a thirst quencher. Klugh ('27, p. 22) writes that "The favorite beverage of the red squirrel is unquestionably the sap of the sugar maple, and in early spring . . . they spend a large part of their time drinking sap. They obtain the sap in three ways: from that which runs down the underside of branches which have been broken off by the winds of late autumn and winter, from the holes drilled by the yellow-bellied sapsucker and from incisions which they make for themselves. The former source of the sap flow is by far the most important as a heavy flow of sap often proceeds from the ends of these broken branches, and in availing themselves of it the squirrels hang on to the underside of limbs, both small and large." Stone and Cram ('03, pp. 174-175) refer to the tapping of maples by the squirrels gnawing saucer-shaped cavities on the upper side of the limb, from which they drink the sap that collects. Klugh ('18, p. 9) states that a certain squirrel under observation drank this sap in late March. Cram ('99, p. 216) also refers to the tapping of maples in March, and further p. 219) states that they may take advantage of the downward flow of sap in autumn. Klugh ('27, p. 23) says that the squirrels also lick the icicles of sap which form during the night.

Silver Maple (*Acer saccharinum*). In the early morning of April 16, I watched a red squirrel feed on the buds of a silver maple at Katonah, New York. In nipping off the buds the squirrel occasionally drew towards him with his paws the twigs bearing them. The majority of the buds on one limb were consumed as I watched.

The flower buds of the silver maple are also eaten by the red squirrel, according to Merriam ('84, p. 214).

Red Maple (*Acer rubrum*). Many keys, split open and with the seeds removed, were found beneath a red maple at Speculator, New York, June 24. I saw a red squirrel feeding in the tree. Merriam ('84, p. 214) long ago had observed the red squirrel feeding on the seeds of this species.

Referring to the soft maple, by which I presume is meant *Acer rubrum*, Klugh ('27, p. 16) states that the red squirrels eat not only the keys, but also the buds and the leaf petioles.

Basswood (*Tilia americana*). September 5, my Adirondacks captives were fed the fruit of this tree. They cut the seeds free from the stem, opened the nut-like drupes on one side and ate the inner tissues. I did not see any wild squirrels feeding in basswood trees.

White Ash (*Fraxinus Americana*). May 8, at Katonah, New York, I saw a red squirrel feed on the opening buds of a group of three white ash trees. At the rate it was feeding I judged that the squirrel might have completely defoliated the trees in a few days.

SHRUBS

Yew (*Taxus canadensis*). Some ripe berries of a yew which I placed in the cage of a captive squirrel on Valcour Island were eaten.

Juniper (*Juniperus communis* var. *depressa*). The seeds from the berry of this shrub, which I offered to my captive squirrels were eaten, but the remainder of the fruit was left untouched.

Greenbrier (*Smilax rotundifolia*). During a winter famine among the red squirrels an individual under the observation of Walton ('03, p. 91) ate sparingly of the sweetish tasting fruits of this plant.

Hazel (*Corylus americana* and *C. rostrata*). Red squirrels store and eat the nuts of both our species of hazel whenever available.

At Lake Placid, New York, August 14, I saw the red squirrels engaged in cutting down and eating the full sized, though green, hazelnuts (*C. rostrata*). At Petersham, Massachusetts, the squirrels were harvesting the nuts from August 8 to September 4 or longer.

In this nut gathering a squirrel which I watched proceeded apparently entirely by the trial and error method. It gave no evidence of being guided by inspection first as to whether or not a nut grew on a particular branch. The ascent was made, and if none were found another branch was tried. Frequently the hazel would bend under the weight of the squirrel until its top reached the ground.

The myriad glandular hairs which cover the husk of the beaked hazelnut would seem to be an adequate defense against the red squirrel, which, however, appears to suffer no harmful effects from them.

The question may be asked at this point whether the squirrel can tell a good nut from a bad one before opening it. Out of 245 beaked hazelnuts supplied to a pair of my captive red squirrels on August 21, 202 were eaten. Of the 43 nuts that remained, 4 had been partly opened, but each contained an undeveloped kernel. The remaining 39 had neither been husked nor shelled, but examination showed that 28 of these were apparently well developed. Weight records showed, however, that the average weight of these nuts was 1.15 grams as against our average of 1.75 grams for the entire lot before it was placed before the squirrels. Walton ('03, pp. 85-86) writes: "I noticed that he [a red squirrel] left many nuts on the bushes, but when I investigated I found a worm in each nut. A good reason for rejecting them; but as the husks seemed perfect, how did Bismarck know the worms were there? I think his keen scent was the secret. By the sense of smell he could tell a wormy from a sound nut. So could I after the nut was smashed, but not before."

Alder (*Alnus* sp.). Murie ('27, p. 39) describes a red squirrel cache in Alaska, containing two bushels of alder cones.

Barberry (*Berberis* sp.). Walton ('03, p. 91) writes of the barberry being used as a famine food in winter, when it has lost much of its usual sourness. Lottridge ('17, p. 168) also lists this food.

Gooseberry (*Ribes Cynosbati*). Late in August I observed the squirrels on Valcour Island eating gooseberries, feeding from one side of the berry only, as though to avoid the thorns. Klugh ('27, p. 17) likewise records this food.

Currant (*Ribes* sp.). Wild red currants were eaten by my captive squirrels at Long Lake, New York, July 27; and wild black currants, on Valcour Island, August 25. Klugh ('27, p. 17) records red squirrels stealing white and red cultivated currants at Fergus, Ontario.

Chokeberry (*Pyrus melanocarpa*). Listed by Walton ('03, p. 91) as a winter food of the red squirrel.

Purple-flowering Raspberry (*Rubus odoratus*). On Valcour Island, August 25, I saw a red squirrel feeding on this fruit.

Red Raspberry (*Rubus idaeus*, var. *aculeatissimus*) etc. These berries were eaten by my red squirrels at Long Lake, July 27, and Adams ('09, p. 399) has listed them as a squirrel food at Isle Royal, Michigan. Klugh ('27, p. 17) saw the red squirrel eat the fruit of *Rubus strigosus*. From the stomach of a red squirrel I took in late July the seeds of a dwarf red bramble that grew in the clearing in which the squirrel was shot at Long Lake.

Rose (*Rosa* spp.). The haws of the smooth rose (*Rosa blanda*) were eaten by my captives on Valcour Island; but Klugh ('27, p. 17) says that the fruits of *Rosa virginiana lucida* are rarely eaten by the red squirrel. Walton ('03, p. 91) states that rose hips were eaten occasionally in winter by the red squirrels on Cape Ann, Massachusetts.

Staghorn Sumach (*Rhus typhina*). The seeds of staghorn sumach were, according to Walton ('03, p. 91), used sparingly as a winter food by the red squirrels on Cape Ann; and Burroughs ('01, p. 11) mentions squirrels feeding on "sumac bobs" in winter.

Wintergreen (*Gaultheria procumbens*). The berries of wintergreen were eaten by red squirrels on Cape Ann, as soon as the melting of the snow uncovered them, writes Walton ('03, p. 92).

Blueberry (*Vaccinium vacillans*). The late low blueberry was eaten both by wild and captive red squirrels during my observations at Petersham, Massachusetts, late in August. This food often colored the stomach contents of squirrels taken in that period.

Partridge Berry (*Mitchella repens*). The berries are eaten in early spring when the snow melts (Walton, '03, p. 92).

High-bush Cranberry (*Viburnum pauciflorum*). Murie ('27, p. 39) describes a cache in Alaska, containing about two bushels of these berries.

Elderberry (*Sambucus* spp.). Klugh ('27, p. 17) writes that he had seen the red squirrel eat the fruits of both the red (*S. racemosa*) and the black (*S. canadensis*) elderberry.

HERBS

A number of herbaceous plants serve as food for the red squirrel at odd times, and in the aggregate are doubtless an important part of the animal's sustenance; but compared with trees, shrubs, mushrooms and flesh, these lowly plants appear to be complementary only.

As to the grasses, Klugh ('27, p. 18) publishes an account furnished by A. H. Leim, of red squirrels eating the seeds from the heads of timothy (*Phleum pratense*) and orchard grass (*Dactylis glomerata*). The squirrels went to considerable trouble to reach these heads. That these animals feed on wheat and rye is stated by De Kay ('42, p. 62), while Stone and Cram ('03, p. 174) and others write that they eat corn. My captive squirrels would never eat fresh corn, but they frequently ate corn meal.

A bushel of the seeds of cow parsnip (*Heracleum lanatum*) were found stored by red squirrels in an Alaska cabin, writes Murie ('27, p. 39), on the report of Otto Geist. And I was told by Professor George Hudson that the squirrels had cut large ripe tomatoes from the vines in a garden on Valcour Island and had attempted to carry these straight up the trunk of a tree, but time after time they were forced to drop the fruit. When a tomato by this repeated dropping became too soft the squirrel would go and find another. Occasionally the animals would succeed in getting one into a crotch where it would be stored.

Other herbaceous plants on parts of which the red squirrel has been known to feed are wild strawberries, which, when given to my captive squirrels, were always eaten immediately; sunflower seeds, which my captives seemed to enjoy; ground cherry (*Physalis pubescens*), listed by Johnson ('24, p. 137); the fruit of the bunchberry (*Cornus canadensis*), listed by Klugh ('27, p. 17); and roots (Osgood and Bishop, '00, p. 27), though what species is not mentioned.

FUNGI

The red squirrel eats and stores fresh mushrooms of many species. In Massachusetts, the earliest I found them feeding on fungi was on June 30, though it is probable that some of the earlier spring species are utilized also. Throughout the summer, principally in August, the mushrooms are eaten in considerable quantity, and throughout the winter such stores are drawn upon.

The squirrel's avoidance of poisonous mushrooms is often discussed. Walton ('03, p. 82) declares he has followed the red squirrel's choice and has eaten those and only those species which the squirrel chose. Ballou ('27, p. 57) concludes that the squirrel alone among animals is possessed of the ability to distinguish between edible and poisonous forms. I believe that there is ample evidence in my notes with reference to *Amanita muscaria* to justify the opinion that in the case of the squirrel we are dealing with a tolerance or immunity to mushroom poison rather than with an ability to distinguish between nonpoisonous and poisonous forms.

Amanita muscaria (Fly amanita). The red squirrel eats this mushroom quite commonly without any immediate harm, at least. This species of mushroom

contains an alkaloid poison, muscarine, which in man paralyzes the nerves controlling the heart. It is said that this species killed the Czar Alexis of Russia and the Count de Vecchi of Washington, yet it is known to be used as an intoxicant by some of the Russians.

Taken in very small amounts, it is said to produce dizziness, pallor, exaggeration of vision and nausea. Its juices injected into the blood of etherized cats will produce death in less than one minute.

My captive squirrels preferred the fly amanita to all other mushrooms, except *Russula emetica*, and ate heavily of it, yet never became ill as a result. In the 1926 mushroom season in the Adirondacks, from July 29 to September 1, *Amanita muscaria* and *Russula emetica* were the mushrooms chiefly utilized by wild squirrels. The pileus and gills only were eaten as the stem is hard and evidently less palatable.

I have found the red squirrel feeding on *Amanita muscaria* at Petersham, Massachusetts (July 6), in the Adirondacks (July 29 to August 15), and on Valcour Island, Lake Champlain (August 27 to Sept. 1). At Bedford, New York, I have found the fly amanita partly eaten in late August, presumably by a red squirrel. Odell ('25, pp. 180-181 and '26, p. 184) records the finding near Ottawa of partly eaten and stored parts of the fly amanita, almost certainly the work of red squirrels. One of these is recorded after a frost, October 9. Hastings and Mottram ('16, pp. 369-371) conducted feeding experiments in England on captive American squirrels, said to be *Sciurus cinereus* [*S. uiger ueglectus* or *S. carolinensis*]. *Amanita muscaria* was offered only before the ground became frozen. These mushrooms were eaten on six occasions, nibbled once, and refused four times. They say that "the experiments also show that fungi poisonous to man are not unpalatable to squirrels It is noteworthy however that the American squirrel was used and that therefore neither the animals nor their ancestors can have had much experience of English fungi." I presume that *Amanita muscaria* of North America is specifically identical with that of England and Europe, though I do not know that the species of squirrels which the authors used ever fed on *Amanita muscaria* here.

Amanita phalloides ("Destroying Angel"). Walton ('03, p. 82) says that about his cabin both the red squirrel and the "Destroying Angel" were common, but that he never saw the tooth mark of a squirrel on this mushroom. Ballou ('27, pp. 57-58) maintains that the squirrels avoid this species. Cram ('99, p. 205), however, records red squirrels eating the "white Amanita."

Amanitopsis vaginata var. *alba*. The cap, gills and stem of this species were eaten by my captives, July 30 to August 19.

Armillaria mellea (Honey Fungus). Buller ('20, p. 356) records red squirrels at Kenora, Lake of the Woods, Ontario, eating and storing this species in early October.

Boletinus cavipes. One specimen was found stored in a tree on Valcour Island; but these mushrooms, which were common in the woods, were not otherwise seen to be touched. Captive squirrels would not eat them.

Boletus bovinus. Hastings and Mottram ('16, pp. 369-371) report that their captive "*Sciurus cinereus*," when offered this mushroom after the ground was



Fig. 44. *Russula roseipes* (?) eaten in situ by a red squirrel. Valcour Island, Lake Champlain. August 27, 1926.



Fig. 45. *Boletus* sp. eaten in situ by a red squirrel. Petersham, Mass. June 30, 1925.



Fig. 46. Red squirrel midden at base of red spruce. Long Lake. July 25, 1926.



Fig. 47. Red squirrel cone litter on a fence. A squirrel used this site for sun baths as well as for feeding. Valcour Island, Lake Champlain. September 8, 1926.

frozen, ate it twice, nibbled at it on two occasions, and three times refused it entirely.

Boletus castaneus. When I offered this mushroom to my Adirondack captive squirrels they took a few bites from the cap, but very little of it was eaten.

Boletus cyanescens. Left untouched by my captives. This is reputed to be a poisonous species.

Boletus (scaber?). At Long Lake, July 13, a *Boletus*, probably *B. scaber*, was found which had had several bites taken from its cap by a red squirrel.

Bolctus variegatus. This species given to their captive "*Sciurus cinereus*" by Hastings and Mottram ('16, pp. 369-371), at a time when the ground was frozen, was eaten on three different occasions and merely nibbled on three others.

Cantharellus aurantiacus. Four times nibbled and five times refused by captive "*Sciurus cinereus*" of Hastings and Mottram (op. cit.).

Cantharellus cibarius. Red squirrels at Petersham, Massachusetts, fed on this fragrant mushroom during July, and my captive squirrels on Valcour Island nibbled from its stem. Klugh ('27, p. 17) previously had seen squirrels feed on this mushroom.

Cantharellus flaccosus. Cap and gills of this species were eaten by captive squirrels, July 30.

Clavaria aurea. Klugh ('27, p. 17) reports seeing the red squirrel eat this species. My mushroom specimens of this genus could not be positively determined, but one species (*C. flava?*) was refused by my squirrels, and another eaten.

Clitocybe brunalis. Nibbled once and twice refused by captive "*Sciurus cinereus*" of Hastings and Mottram ('16, pp. 369-371).

Clitocybe virens. The gills and the underside of the cap of this species were commonly eaten by the squirrels on Valcour Island, in late August and early September. The pileus, which is leathery, is not eaten. Captive squirrels ate sparingly of this species.

Collybia maculata. Before the ground froze the "*S. cinereus*" of Hastings and Mottram (op. cit.) ate of this species twice, nibbled the food five times and refused it four times. After the ground was frozen this mushroom was eaten three times, nibbled twice, and never refused.

Collybia radicata. Klugh ('27, p. 17) saw a red squirrel eating this fungus.

Cortinarius. Buller ('20, p. 356) writes on the report of Stuart Criddle of Treesbank, Manitoba, that mushrooms of this genus were taken from a large cache of the red squirrel. My squirrels when given this mushroom nibbled of all parts of it as though to taste it, but did not eat it.

Flammula sapinea. This was twice nibbled and twice refused by "*S. cinereus*" of Hastings and Mottram (op. cit., pp. 369-371), who also reports (p. 366) a squirrel near Vilna eating a species of *Flammula*.

Hygrophorus pudorinus. October 9, near Ottawa, this fungus was being eaten and stored by red squirrels, according to Odell ('25, pp. 180-181). My captives refused the only representative of this genus (species undetermined) that I offered them. Hastings and Mottram (op. cit., pp. 369-371) report that before the ground was frozen "*S. cinereus*" ate *H. hypothysus* twice, nibbled at it five times and refused it once. After the ground had frozen the squirrels ate this mushroom on nine occasions, nibbled at it twice and refused it twice.

Hypholoma fasciculare. Buller ('20, p. 356), quoting Stuart Criddle of Treesbank, Manitoba, writes that a *Hypholoma*, probably *H. fasciculare*, was found among other species in a squirrel cache.

Lactarius piperatus. Part of the pileus and flesh of a mushroom of this species was eaten by one of my captive squirrels. Buller ('20, p. 356) writes that E. M. Gilbert has seen a red squirrel in Wisconsin feed on *L. piperatus*, parasitized by *Hypomyces lactifluorum*; and that *H. piperatus* was found in a cache described by Stuart Criddle. I found these mushrooms partly eaten late in August, on Valcour Island.

Lepiota naucinoides. Klugh ('27, p. 17) reports seeing a squirrel eat this species.

Morchella esculenta and *M. conica* (Morrell). Both these forms are eaten by the red squirrel, according to Klugh ('27, p. 17).

Paxillus involutus. Hastings and Mottram (op. cit., pp. 369-371) fed this species to "*S. cinereus*" in captivity. Before the ground was frozen the squirrels nibbled the food once and refused it eight times. After the ground was frozen they ate it on five occasions and nibbled it on seven.

Pleurotus ostreatus. Klugh ('27, p. 17) records having seen red squirrels eat this species.

Russula emetica. Among the red squirrels in the Adirondacks this seems to be the most frequently eaten mushroom, and with my captives it was the favorite. Scarcely a specimen found in the woods would be intact where squirrels were common. Though this mushroom is by some people considered poisonous, or a strong emetic—and by experience I may say that when fresh it has a strong peppery taste which makes it unpalatable—others tell me that they have frequently eaten the species cooked and found it edible and harmless. Certainly the squirrels eat great quantities of it with no ill effects.

Russula rosicipes. On Valcour Island this species appear to play the same rôle in red squirrel diet as did *R. emetica* in the Adirondacks, unless these species have been confused. Klugh ('27, p. 17) writes that he has watched the red squirrels feed on *Russula* of many species. Other authors give many records of the usefulness of this genus to the red squirrel without designating the species concerned.

Tricholoma equestre. Odell ('25, pp. 180-181) found this species stored and later eaten by red squirrels near Ottawa, on October 9.

Fungi refused. My captive red squirrels have refused the following fungi when offered to them: *Agaricus sylvestris*, *Boletinus* sp., *Boletus* sp., *Calvatia* sp., *Clavaria* sp., *Hygrophorus* sp., *Hydnum scrobiculatum*, *Hydnum* sp., *Pluteus* sp. and *Russula* sp.

Underground fungi. The red squirrel and its relatives dig into the earth to secure several of the underground fungi. On Valcour Island, August 20, I found a specimen of the strongly pungent, truffle-like *Gautieria morchelliformis* quite recently stored by a red squirrel in an arbor vitae. Du Beau ('12, p. 41) writes that in Anjou, *Balsemia vulgaris* is dug up and eaten by the squirrels [*Sciurus vulgaris*] and that these mushrooms are found by human mushroom gatherers by looking for the little round holes made by the squirrels, easily dis-

tinguishable from somewhat similar holes made by the rabbits, since the latter are oval and the earth is thrown out on one side only, while those made by the squirrel are circular and the earth is thrown out all around. Langham ('16, p. 136) writes of the squirrels in Ireland eating the foul-smelling *Melanogaster ambiguus*. Captive American fox [?] squirrels in England nibbled the false truffle, *Elaphomyces granulatus*, which is said (Hastings and Mottram, op. cit., 369-371) to be eaten by the free wild squirrels. This fungus grows about three inches under ground.

It seems that it is probably the odor of these subterranean fungi rather than their food value, which makes them sought after. Do the truffles and false truffles, which in old age are often strong-smelling, depend on the mammals (squirrels, rabbits, pigs, etc.) to scatter their spores? Spores of *Elaphomyces* pass through the alimentary canal of mammals unchanged.

ANIMAL MATTER

Though the squirrel is only occasionally predatory on birds and probably never on other vertebrates, meat is readily accepted as food.

Spreadborough ('19, p. 61) states that in winter the red squirrel will eat frozen beef and that numbers are caught in steel traps baited with meat and set for weasels and marten. Dice and Sherman ('22, p. 38) write of a squirrel which fed ravenously on the kidney of a recently killed woodchuck. Walton ('03, p. 89) writes of their storing and eating old bones, and further (p. 91), that the squirrels eat all kinds of meat, even fat pork, and that cooked meat is preferred to raw.

I found a ball of red squirrel hair the size of a pea in the stomach of a pregnant female taken July 19. It seems likely that this hair had accumulated from repeated dressing of the fur rather than as a result of cannibalistic habits.

Among the birds the red squirrels are given to occasional depredations, as related in another section of this paper. Among domestic birds there are a few additional cases known. Buller ('20, p. 302), quoting a letter from J. B. Wallis, Principal of the Machray School, Winnipeg, says: "A red squirrel had taken up its abode just behind a farmhouse near Thornhill, a village some eighty miles W.S.W. of Winnipeg. This squirrel had become quite friendly and showed no fear of its human neighbors. One day whilst visiting the house I was called outside and there was the squirrel laboriously dragging by the neck up a small oak tree, a chicken nearly as big as itself. On looking more closely two other chickens were discovered, hung by their heads in forked branches. The three chickens had all been killed by bites at the back of the head. The squirrel on perceiving my friend and myself immediately seemed to sense disapproval of his thrifty habits and retired rapidly to a high bough from whence he was dislodged with a charge of number six shot. As a really advanced squirrel he thus fell a victim to his very advancement." A similar incident is given by Bruce ('98, p. 379).

Merriam ('84, p. 216) also gives the record of a red squirrel killing young chickens and ducks in a poultry yard; and Dice ('21, p. 25) writes of a squirrel storing a grouse head in an Alaskan cabin.

Land snails were at times removed from their shells and eaten by my captive squirrels. A crayfish introduced into the cage was not eaten, though the squirrel

which investigated it, after being pinched several times for this indiscreet curiosity, retaliated with a nip on one of the chelae.

Insects are probably eaten extensively by the red squirrels since they may be rather plentiful when much other food is scarce. Cram ('99, p. 202) writes that "occasionally you will see one [red squirrel] clinging to the bark of some dead pine or hemlock and listening woodpecker-like to the sounds made by the insects at work beneath the surface. When he has succeeded in locating the prey he tears off the loose bark with his teeth in great ragged pieces and presently pounces upon and drags forth a flattened white grub an inch or more in length which he devours with apparent great relish." Cram (op. cit., p. 221) states further that the squirrels often eat grasshoppers and other insects in summer.

Seton ('09, pp. 322-323) mentions that in the Selkirk Mountains, on August 17, he watched the squirrels eagerly eating "worms" that infested a sort of gall formed in the spruce trees. Further ('28, p. 133), he quotes Mrs. R. G. Taylor as describing the act of a red squirrel which fed upon the grub-filled comb in a paper hornet's nest which had been burned out the day before. Klugh ('27, p. 18) writes that he has seen them eat the larvae and sometimes the pupae of several kinds of insects. On June 26 I saw a young red squirrel at Bedford, New York, crawl out on the small branches of an apple tree, cut off one curled leaf after another and eat the plant lice found on them there in great numbers. Davis ('07, p. 16), at Lakehurst, New Jersey, in the pitch pine midden of a red squirrel, found a number of cocoons of *Clisiocampa*. They had been secured in a nearby wild cherry tree which had been badly defoliated by these larvae, and which still contained some of their tents. The squirrels had opened each cocoon either at the end or on the side and had extracted the pupae.

On Staten Island, New York, during August and September, acorns of red and scarlet oaks fall with cups attached. In many of these are the larvae of *Balaninus* which at this stage are said to be much sought after by the gray squirrels. These squirrels appear to detect the presence of the larva by biting off a small part of the cup so as to expose the base of the acorn, which they then puncture slightly. The odor then probably indicates the presence or absence of the larva. McAtee ('26, p. 416) states that arboreal squirrels sometimes feed largely on scale insects and other tree pests. Possibly the red squirrel is one given to such habits.

STOMACH CONTENTS

The food of the squirrel is so thoroughly chewed before being swallowed that it is usually very difficult to determine the composition of the finely ground mass. Occasionally the odor will furnish the clue, as in the case of spruce seeds and hazelnuts. Color is imparted to the contents by blueberries and raspberries, the unchewed seeds of which may also occasionally be found in the stomach. Hair and feathers may easily be recognized. On one occasion I found an entire spruce needle in the stomach of a red squirrel, but this may have been accidentally swallowed during its death struggle.

The average weight of twenty-four red squirrel stomachs and their contents, taken between late June and early September, was 5.8 grams. The heaviest weighed 19.0 grams and was taken from an adult male weighing 206 grams.

shot July 21, at 2:00 p. m. The lightest weighed 1.5 grams and was from an immature male weighing 126 grams, taken July 26, at 9:15 a. m. Only in a general way was there a correlation between the total weight of the squirrels and the stomach weight. The heaviest stomachs of the series all came from heavy squirrels. The hour at which the squirrels were shot made no appreciable difference. Heavy and light stomachs were secured at all periods of the day.

Food habits. In early spring the red squirrel is largely dependent on the buried stores of the previous season and on the winter buds of trees, just as it is in the depth of the winter. Following the thaw, the flowing sap, leaf buds, flower buds and the bark of trees offer variety in its diet. Flowers and leaves follow in their turn; thereupon nesting birds and insect life furnish certain additional items of food to the squirrel.

In early summer the buried stores as well as the new crop of spruce cones, mushrooms, seeds and fruits of many trees, certain insects, occasional birds' eggs and nestlings form the bulk of the diet. As summer advances nuts, fruits, cones and mushrooms become increasingly important items in its bill of fare.

The advent of the fall season is accompanied by increased activity on the part of the squirrels in storing all late ripening nuts, fruits, cones and mushrooms. Until the arrival of snow such food is abundant.

Food stored in trees and in the ground forms the bulk of the winter supply. Foraging activities uncover other food from time to time to augment the larder. While occasional chance offerings must be welcome, it is in the season of snow that the labors of summer and autumn bear their great reward.

Food gathering. Food harvested for future use is apt to be gathered hurriedly, a large quantity cut first and stored later. Thus in cutting the fruits of trees, if the squirrel is not working in competition with other species, it will first cut down many fruits, and later, descending to the ground, will store them. Ground plants such as mushrooms are, however, stored as gathered.

In gathering spruce cones, writes Bell ('98, p. 76), "The chickaree selects a tree which either because of the steepness and density of its upper parts, or because of its leaning to one side, makes it certain that the cones, if detached, will fall to the ground; then he cuts off the heavily laden branches and lets them drop. This is done with an impatient rapidity. These branches seldom lodge in the branches below, but should a squirrel on his way down notice one of them in a hopeful position towards the extremity of a bough he will sometimes run out and give it a second send off."

Dice ('21, p. 25) writes: "The cones may be cut singly, but often they are cut in the natural clusters of several cones and stored in that shape. September 6, 1911, near Tanana [Alaska], a red squirrel was watched while he was cutting cones from the top of a high white spruce. The cones were thrown away from the tree by a backward toss of his head and fell in all directions. He seemed to have no regular method of going over a branch for its cones, and I think several times returned to the same branch. During fifteen minutes he worked continuously, dropping cones sometimes one per second, though they usually fell more slowly." Klugh ('27, p. 20) writes, on the report of J. N. Gowanloch, that "A single

squirrel to a tree would spend three hours or more cutting off cones and then in the afternoon would carry off the cones and deposit them in holes under the roots of trees." On Valcour Island, August 22, I found the ground under many balsams heavily littered with cut twigs to many of which the cones were still attached. One squirrel which I watched cut down cones for about half an hour, letting them fall as they would, and later descended to trim and hide them. Occasionally the squirrel would interrupt its storage activities to climb up into the tree and bring down another cone.

The cones are always cut by the squirrels before they have become dry and their seeds scattered. Thoreau ('06, p. 196) writes: "I think moreover that their design if I may so speak, in cutting them off green, is partly to prevent their opening and losing their seeds for these are the ones for which they dig through the snow and the only white pine cones which contain anything in them."

Most nuts are likewise commonly cut green, though some species are allowed to remain on the tree until they ripen. Seton ('09, pp. 324-325) writes: "The habit of cutting off the chestnuts before they are ripe is very marked among the Connecticut squirrels and is at times somewhat puzzling. The nuts would be much better if left a fortnight longer, and by throwing them to the ground all are brought within reach of many rivals. The explanation lies in the fact that the red squirrel has been evolved to prey on the seeds of conifers." Thoreau ('06, p. 194) says: "In the fall I notice on the ground, either within or in the neighborhood of oak woods . . . stout oak twigs three or four inches long, bearing half a dozen empty acorn cups, which twigs have been gnawed off by squirrels on both sides of the nuts in order to make them more portable."

Audubon and Bachman ('49, p. 129) note that "It advances as near to the extremity of the branch as it can safely and gnaws off that portion on which the nuts are dependent. This is usually done early in the morning. . . . Some of the stems attached to the nuts are ten inches or a foot in length. After having thrown down a considerable quantity the squirrel descends and drags them into a heap."

In gathering hazelnuts, writes Walton ('03, p. 85), "Bismarck [the squirrel previously mentioned] did a lot of running for he carried but one nut at a time. He always worked under high pressure, running to and fro at the top of his speed."

In cutting such fruits as those of elm and maple, whole clusters together with their branch tips and leaves are nipped off and dropped to the ground below. Beneath an American elm near Speculator, New York, for several days in mid-June I found hundreds of branch tips from this tree. These usually bore four or five leaves and a small cluster of seeds. The twigs averaged five inches in length. In feeding in this and in an adjacent tree one of the squirrels cut off seed clusters in random fashion, taking a cluster of seeds from one branch and then one or several clusters from other branches, only to return again to the first. If a cluster was conveniently within reach the fruits only would be cut off; but if the reach was too great the supporting twig was cut, about a third of the seeds eaten, and the remainder dropped. In ten minutes of watching the squirrel dropped

seven twigs to the ground; but it ate more or less from twice as many clusters cut off in that time.

In gathering mushrooms the squirrel seizes one by the stem and carries it as nearly horizontally as its size will permit to the place where it is to be consumed or stored. If the mushroom is large it may break of its own weight or be broken by the squirrel, and the parts carried away one at a time. Seton ('09, pp. 326-327) and Merriam ('84, p. 214) have described such cases.

Buds may be eaten directly from the twig (Scotch pine), or the twig bearing them may first be clipped off (larch, spruce) and the buds then removed more conveniently.

Klugh ('18, p. 10) writes of a red squirrel that carried away a quarter-pound potato. This is probably near the maximum load a squirrel can carry.

Food "preparation." The red squirrel cleans and "prepares" most articles of food before eating or storing them. Twigs and leaves which are attached to cones and nuts when they are cut off are subsequently removed, with the result that the object may be transported with greater facility and stored with less waste of space.

Beads of pitch on the outside of cones infested with cone borers are cut off systematically and quickly by a squirrel before it feeds from or stores the cone. Occasionally in the handling of the cone some pitch sticks to the palms of the squirrel's hands. I have seen a squirrel stop feeding for a few moments to remove this pitch with incisors and tongue. As the squirrel sits upright the cone is grasped with both hands, the pitch removed and the scales clipped off in the order in which they are attached, beginning at the basal end. A swift nip suffices to free a scale on a cone of spruce or of balsam. This is accompanied by a sharp jerk of the head which throws the waste to one side. Another nip is made to lift the seed exposed by the first cut and the seed is eaten. In this fashion the bracts are thrown aside and the seeds eaten from base to tip. Occasionally the squirrel starts at the tip end, more rarely in the middle.

In the course of the feeding operation just described squirrels will occasionally use the rudimentary thumb to lift up a loosened scale rather than cut it in the usual manner.

The catkins of birch are treated in much the same manner as are the cones of spruce. The shuckings from such feeding operations are found on logs, in small middens, as are remnants of cones.

The seed of an elm is removed from its wing by inserting the teeth into the seed from both its faces and so pulling the seed free from the fruit in one operation.

Before feeding on or storing the beaked hazelnut, the squirrel removes the long extension of the husk forming the beak. Before the nut is eaten, but not before storage, the remainder of the husk is removed and the shell opened, just enough to allow the entire contents to be removed. It would seem almost incredible if the squirrel did not get thousands of the glandular hairs of the husk into its mouth while removing this from the nut; and still more remarkable if these did not cause the animal considerable pain. Yet the wild squirrels feed on these nuts

extensively. The husk of the smooth hazelnut is removed before the nut is eaten. I have never found this species stored.

Hickory nuts, walnuts and butternuts are opened after the husk has been removed, by gnawing a hole on the side, usually near the apex, sufficiently large to get at all of the kernel. Burroughs ('01, p. 13), in writing of the opening of a butternut by the squirrel, says: "He always gnaws through the shell so as to strike the kernel broadside, and thus easily extract it; while to my eyes there is no external mark or indication in the form or appearance of the nut . . . by which I can tell whether the edge or the side of the meat is toward me . . . Occasionally one makes a mistake, but not often." Seton ('09, p. 324) writes that "It never strikes a butternut on the thick end or makes the mistake of chiseling into a nut that does not repay the trouble. Sound-looking nuts picked up at a squirrel's laboratory are invariably found to be empty." Walton ('03, pp. 85-86) states that hazelnuts which were left on the bushes by the red squirrel were invariably found to be wormy.

Acorns and chestnuts are opened by tearing or gnawing off almost any part of the comparatively thin shell. Occasionally the whole shell is removed before the kernel is eaten. "In eating a beechnut the squirrel pulls off one side with his teeth, and removes the kernel whole," according to Klugh ('18, p. 10).

Mushrooms are eaten as they stand (Figs. 44 and 45) or after being pulled up. If the pileus of a species is not eaten it is often pulled off first. The stem in those species in which it is hard is not touched.

"Every spring," writes Walton ('03, p. 94), "Bismarck taps the trees around my cabin. He begins on the maples and ends later on the birches. If the tree is small he taps the trunk, if large, he works on the limbs. He gnaws through the bark and into the wood, then clings to the limb or trunk below the wound while he laps the sweet sap. If there is a hollow in the bark into which the sap flows, Bismarck is sure to find it."

Klugh ('27, p. 23) states that squirrels often hang to the underside of limbs to lap up sap.

Middens. The most conspicuous and lasting litter or midden left by red squirrels is that resulting from their feeding on the seeds of conifers. Such midden heaps are found at the habitual feeding spots and their size depends upon the species of conifer, the proportion of the squirrel's diet that the seeds compose, the age of the stand and of its squirrel population, and the number of squirrels using the feeding place. Those relatives of the eastern chickaree which inhabit the western mountains and the far North feed more extensively on conifers than do their eastern representatives, and therefore the middens here attain their largest size. The largest which I have found recorded is the following (Murie, '27, p. 39): "Roy King of Bettles [Alaska] told me of a large mound of cone scales in a dense thicket of small spruce, the heap measuring nine feet or more in height and more than twelve feet in diameter. Such heaps are often perforated by tunnels, possibly leading to storerooms or shelter." Osgood and Bishop ('00, p. 27) describes a midden of conifer scales in Alaska twenty feet square and six inches deep.

A white pine midden in North Central Massachusetts averaged eighteen inches in diameter and three to four inches deep. Spruce and balsam middens in New

York State were larger, some being as much as five feet in diameter, though only three to four inches deep. In spruce swamps the middens are commonly on the tops of stumps (Figs. 38 and 39).

Middens of nut trees, of barking operations and of elm and maple seed feasts are common, but these are not usually in such well formed heaps as the conifer débris. Hazelnuts are found in good sized middens, but these disappear between the feeding seasons. Seton ('09, p. 324) writes that "The workshop where the squirrel thus prepares its food is much marked by heaps of the hulls, rubbish and rejected nuts, but these are never left near the actual store."

Food storage. Hand in hand with the necessity of a year round food supply necessitated by an active winter life there has been developed in our northern squirrels a strong instinct for food storage. Not only do these squirrels labor industriously in the season of plenty to set aside large stores of cones, nuts and mushrooms for winter use, but nearly every left-over piece of food is placed away somewhere, probably to be forgotten and perhaps rediscovered. The fragments of a partly eaten mushroom, a partly eaten nut, or even a fledgling bird which would soon rot, will be carefully placed away in the fork of a branch or in a crevice in the bark. Klug ('27, p. 21) says that some of these stores are temporary and the squirrel may return in a few minutes, hours or days later to haul forth the object and finish it, or merely eat a little more of it and store the rest away again. Seton ('09, p. 326) notes a difference between the gray squirrels and the red squirrels in this respect. He writes that "The grays sit down and eat their food where they find it. The reds carry it away to eat. The grays lose interest when their bellies are full. The reds carry away everything, storing what they cannot eat." Buller ('20, pp. 361-362) has pointed out that the squirrels in England do not store mushrooms, as they would rot before they were dry. In Northern North America the mushrooms stored in holes may be preserved by frost even though they did not become quite dry.

Food stuffs are stored separately in little pockets in the ground or among the branches of a tree. Collectively they are stored temporarily in heaps on the ground or for longer periods in large underground vaults, in hollow logs or trees and in abandoned cabins. The underground storage chambers are usually under the roots of a tree or a stump or under a boulder. Klugh ('27, p. 19), Audubon and Bachman ('49, p. 129) and others note that one squirrel uses several such storage places. Obviously it doesn't put all its eggs in one basket.

The red squirrel, Klugh ('27, p. 19) thinks, classifies food material as hard or soft. Hard objects such as nuts and seeds are buried or stored centrally. Soft objects, such as meat, fruits, and fungi, are separately tucked away in the branches of a tree. Other factors may, however, modify such behavior. Walton ('03, p. 80) writes that "Bismarck did not always hide bread beneath pine needles or leaves. At a certain season of the year the trees about my cabin were made into storehouses. This season was governed by the blue jays. When they were nesting they did not come to the cabin and Bismarck could store food in the trees without fear of being robbed."

Some care is given by the squirrel to the stored food after it has once been gathered. Audubon and Bachman ('49, p. 129) write that, "When for instance

nuts are abundant in the autumn, large quantities in the green state, covered by their thick envelope, are collected in a heap near the tree whence they have fallen. They are then covered up with leaves until the pericarp or thick outer covering either falls off or opens, when the squirrel is able to carry off the nuts more conveniently." Cram ('24, p. 37) writes with reference to mushrooms, that after drying for a few days or a week, according to the weather, they are transferred to hollow trees, to tree nests or to underground holes. Dice ('21, p. 25), in describing a mushroom store in an Alaskan cabin, notes that "Those not entirely dry were spread out separately from the others." I have seen a squirrel move a hazelnut from one part of a tree to another; and another squirrel removing spruce cones from a ground pocket and carrying them to some other store house, about 4:00 p. m., July 8, at Old Forge, New York. This latter, an adult male, would thrust his head and shoulders into the pocket and haul forth a spruce cone. After a hasty cleaning of his soiled fur he would scamper a hundred feet away to dispose of the cone. Most of the dozen trips which I saw him make were over exactly the same course, partly on fallen logs, partly on the ground. The only cone which I saw him deposit he wedged into a fork in the limb of a dead fallen spruce. A diligent search of this tree revealed only one more stored cone. Apparently the others had been stored elsewhere. The pit from which I saw the squirrel take a dozen nuts had nineteen remaining when the squirrel was interrupted. The cones were a bronzed green and tightly closed. The seeds were not dry, but fleshy and palatable. It is my opinion that the cones had been buried the previous season. The pit was in black, rich and damp humus at the base of a fern. There were no other nearby cavities which had been recently emptied of their stores.

According to Walton ('03, pp. 87-88), nuts which started to germinate in the spring were dug up by the squirrel which then clipped their sprouts and buried them.

The guard kept by a squirrel over its stores is noted under the section on the Sense of Ownership. A related case is presented by Klugh ('27, p. 21), in which two persons had robbed a squirrel of its hoard of butternuts in a hollow tree and "left the nuts in the log some yards from the tree and returned with a wheelbarrow the next morning to fetch them, but the squirrel had been there before them, chewed a hole in the sack and removed every nut to some other storehouse, which they were unable to locate."

The fate of the red squirrel's stores is not always to nourish the industrious animal which stored them. Birds, mice and other creatures are known to rob these hoards, and the temporary deposits on the surface of the ground are most commonly robbed by hogs (Audubon and Bachman, '49, p. 129), chipmunks, mice, and other squirrels. Individual or small underground stores must surely often be forgotten and lost. Twice I have found old dry mushrooms in trees, stored there certainly no less than a year and probably destined never to be used by the squirrels (Fig. 49) which placed them there. Among newly stored mushrooms there is a high percentage of loss for I have found many rotting, many more rendered useless by insect larvae, and some blown from their positions in the trees. Nevertheless, much stored food is used, as is attested by many observers. However, the necessity may not arise. Walton ('03, p. 79) relates that a squirrel in his dooryard

did not disturb the hidden stores so long as other food was available about the cabin.

Throughout July, in the Adirondacks, I found the squirrels feeding on spruce and balsam cones which to all appearances had been buried the previous year. Murrill ('02, p. 26) notes that in the region west of the Yukon, M. W. Gorman has seen the squirrels visiting their tree stored agarics every day, even in the coldest weather; and Buller ('20, p. 360) reports that A. H. Doern observed in a suburb of Winnipeg, in October, a red squirrel storing mushrooms in a tree in his yard. The squirrel fed from these mushrooms throughout the winter. It would nibble one of them for a time and then store it away again in another part of the tree. August 22, on Valcour Island, I saw a red squirrel carrying a dry *Boletus*. On seeing me it dropped the mushroom and ran. The mushroom proved to be a very old dried specimen, probably from the previous summer. Murie ('27, p. 39) has mentioned a red squirrel's store of high bush cranberries in a cabin in Alaska, which it consumed in late winter.

The cones of most of the conifers acceptable to the red squirrel have been found in its stores. The cones of hemlock are an exception, according to Walton ('03, p. 90). These cones are not stored, but are husked at the foot of the tree on which they grew. Other authors (Cram, '99, p. 211; Stone and Cram, '03, p. 174; Klugh, '27, p. 15 and Rowley, '02, p. 35) record similar observations. Bailey ('18, p. 37) observes that the long cones of the mountain white pine are cut off and dragged into piles for winter food, or eaten on the ground as they are too heavy to be held and eaten on the branch of a tree.

Cones are stored in little ground pockets, or in large underground chambers. Bailey ('18, p. 37) states that they are stored under brush heaps as well and under piles of old cone scales. Dice ('21, p. 25), in Alaska, has found them stored in the branches of trees, buried in the ground, or piled on the surface, and stored in old piles of scales. Walton ('03, p. 90) states that on Cape Ann, Massachusetts, the cones of white pine were left on the ground two or three days and then carried entire to the storehouse. This practice I have found widespread in the Northeastern States in the storing of spruce and balsam cones.

Stored cones may be put away singly or collected into vast hoards. Dice ('21, p. 25) records from Alaska that "At the bottoms of the trees in which squirrel nests were placed piles of cones a foot or two in height and extending four or five feet around the tree were made." Grinnell and Storer ('24, p. 206) record a store of white fir cones made by *S. douglasii albolimbatus*, containing 484 cones in a small area. The largest store that I have seen contained 117 balsam cones packed away under a rotten stump, on Valcour Island, September 4.

Nuts and acorns of the species acceptable to the squirrel may be stored singly in the ground; collectively in small pockets in the ground; in the crotches of trees (Klugh, '27, p. 21; Burroughs, '01, p. 12); underneath the loose bark of trees (Gibson, '83, p. 84); in the hollows of trees (Audubon and Bachman, '49, p. 129); in hollow logs (Johnson, '18, p. 54) and in cabins (Walton, '03, p. 87). Johnson (loc. cit.) considered the hollow log to be only a temporary storeroom, used to keep the black squirrels from getting too large a share of the harvest. Hazelnuts which I have found buried singly and collectively were placed on the surface of the earth, below the mat of leaves and pine needles of the forest floor. Buried hazel-

nuts were always placed within a short distance of some such landmark as a tree or a log. I have seen a chickaree carry hazelnuts over one hundred and fifty feet before burying them, and have never seen them carried less than thirty feet.

In burying a single nut, Klugh ('27, p. 21) writes, "it scratches out a hollow with its forepaws, places the nut therein, shoves it in as far as possible with its nose, and then covers it with a few swift strokes from right and left with its forepaws. It performs this operation with great rapidity, but does it so well that when it has buried a nut in a location where there is moss and dead leaves there is no trace of any disturbance." Burial in snow is a similar process, according to Klugh ('18, p. 10).

The removal of one and a half bushels of hickory nuts and chestnuts from a hollow tree occupied by a single pair of red squirrels is recorded by Audubon and Bachman ('49, pp. 128-129). An equally large hoard of butternuts was removed from a hollow tree in Frontenac County, Ontario (Klugh, '27, p. 21); and Johnson ('18, p. 54) writes of finding a half bushel of hickory nuts, with shells still on, stored in a hollow elm log. I have found twenty-eight hazelnuts in seventeen clusters, stored in five small pockets within a distance of two feet of each other. Finley and Finley ('25, p. 142) write of a store of twenty-three hazelnuts in one spot.

Mushrooms are stored entire with stem detached or in fragments. They are most commonly placed among the limbs of trees as if to dry, sometimes to be later removed to a dry cavity. I have found them more abundant in the lower than in the higher branches of trees. Odell ('26, p. 184) found them in branches not over four feet from the ground. At Petersham, Massachusetts, they were usually stored in hemlocks. Buller ('20, p. 36) and Murie ('27, p. 39) report them more common in spruces, in the northern parts of the squirrel's range. According to Buller (p. 356), they are never buried underground, but are often found in deserted woodpecker nesting holes, or other cavities in trees, and in outside birds' nests. Stores in unused buildings are reported by Buller, Dice ('21, p. 25) and Murie ('27, pp. 38-40).

In the limbs of trees mushrooms may be stored with stem down through a fork (Fig. 48); stem up, and the cap supported by a platform of twigs (Fig. 49); on edge, with stem horizontal (Fig. 50); or speared on a small twig (Walton, '03, p. 81). According to Walton, mushrooms were stored in trees by a red squirrel on Cape Ann, Massachusetts, because unlike some other food they would not be stolen by the blue jays.

Seton ('09, p. 326) says of mushrooms stored in trees that "Here they are safe from the snow that would bury them, from the Deer and Field-mouse that would steal them and instead of rotting, they dry up and remain in good order until needed."

Mushrooms appear to be stored in larger quantities in the North than in more temperate climates with a more varied food supply. Murie ('27, pp. 39-40) writes: "In July 1921, while on a visit at Tanana Crossing [Alaska], I found the red squirrels very plentiful, and in practically every spruce where squirrels were found a quantity of mushrooms had been placed, some of them nibbled a little, some completely dried. Mr. Geist described a dead spruce where squirrels were storing mushrooms. He watched them at their work and said that the spruce was 'trimmed



Fig. 48. *Amanita muscaria*, stored stem in a fork of a white pine limb. Valcour Island, Lake Champlain. August 27, 1926.



Fig. 49. *Boletus* sp. stored with stem placed upward across the twigs of a white spruce. Valcour Island, Lake Champlain. August 26, 1926.



Fig. 50. *Clitocybe* sp. stored with cap vertical. Valcour Island, Lake Champlain. September 8, 1926.



Fig. 51. End view of a broken poplar stub showing candles stored by a red squirrel in an abandoned flicker nest cavity. The stub was placed horizontally for convenience in photographing. Valcour Island, Lake Champlain. September 12, 1926.

like a Christmas tree.' Mrs. Murie observed the work of squirrels at Ester, a few miles from Fairbanks, where mushrooms had been brought into a cabin and stored on the rude shelves and in other nooks in the logs, mixed with odds and ends, including nest materials." Preble ('08, p. 171) says that about a half bushel of mushrooms were deposited near a single nest, near Jasper House. Dice ('21, p. 25) describes a large store in an Alaskan cabin, in which many were packed tightly into cans. Buller ('20, p. 356) writes on the authority of Stuart Criddle of Treesbank, Manitoba, that a squirrel's store containing two to three hundred mushrooms and another containing one hundred and sixteen fruit bodies were found in an old box in an unused house. Of these, twenty-two were of the genus *Boletus* and ninety-four of the family *Agaricaceae*. Their total weight was one pound, four and a half ounces. Cram ('24, p. 37) writes, presumably of New England, that the stored mushrooms are often found in groups of several dozen. Klugh ('27, p. 21), referring probably to Ontario, says that he has seen trees which contained as many as twenty mushrooms. In the Adirondacks, on Valcour Island, and in Petersham, Massachusetts, I never found more than six mushrooms in one tree.

Meat is frequently stored, at least temporarily. As mentioned earlier in this paper, I have seen a red squirrel store fledgling birds in the forks of trees during mid-summer; and Buller, as previously quoted ('20, p. 302), has reported a red squirrel storing three chickens in the limbs of trees. Dice ('21, p. 25) found a grouse head stored in an Alaskan cabin. Walton ('03, p. 89) mentions stored bones, and Klugh ('18, p. 10) stored meat, in the snow.

Walton ('03, p. 81) observed squirrels storing bread and apple seeds (p. 92). Murie ('27, pp. 38-39) describes an elaborate Alaskan cabin cache as reported to him by Otto Geist. Here were stored about "two bushels of high-bush cranberries, *Viburnum pauciflorum*, two bushels of alder cones, and nearly a bushel of cow-parship seeds, *Heracleum lanatum*. . . . Most of this material had been piled up in a bunk."

Within one hundred yards of our camp on Valcour Island I found eleven wax candles and candle stubs stored in an old flicker nest in a poplar stub (Fig. 51). The longest candle measured five inches. One of the stubs had been about half chewed up by a red squirrel, the incisor marks showing plainly. There was no nest and no other stored material in the tree cavity. The candles had been stored at least one year as we had had none like them in camp that season.

Drinking. My captives drank from an open dish, regularly and without difficulties. They enjoyed milk as long as it was fresh. Klugh ('27, p. 22) says that he has seen them drink melted snow in the spring, and that they frequently eat snow. Shufeldt ('20, p. 42) observes that "Sometimes it may be noticed that after drinking the red squirrel is attacked by a peculiar fit of something akin to coughing, accompanied by a kind of wheezing and sneezing as though some water had been snuffed up into the nostrils or gotten into the air passages."

The drinking of sap in spring is considered under food habits, as I presume it is not as a means of quenching thirst that they drink it.

RELATIONS TO ASSOCIATED VERTEBRATES

Fish ordinarily play but an insignificant part in the lives of red squirrels, but occasionally a large fish may seize a swimming one. Cole ('22, p. 54) records such a case, in which a thirty-seven inch pike (*Esox lucius*), weighing a little over eleven pounds, contained a full grown red squirrel. "The squirrel was intact, having apparently been devoured quite recently. The fish was caught in Lake Fanny Hoe, Keweenaw County, Michigan, at about 7:00 p. m." Seton ('28, p. 125) quotes William Todd who related to him the instance of a pickerel rising and seizing a red squirrel seen swimming in Baskahegan Lake, Washington County, Maine, about September 10. Green ('11, p. 590) gives a record of two muskalonge caught on the French river, each containing a red squirrel in its stomach. Seton ('09, p. 318) mentions the unusual occurrence of a trout seizing the tail of a squirrel as its owner jerked it up and down over the edge of a pool.

Amphibians probably never enter the lives of red squirrels, unless perhaps on a rare occasion a small frog or a salamander may be eaten.

Reptiles. In the southern part of its range the red squirrel is exposed to danger from snakes. Large black snakes, *Zamenis constrictor* (Linn.), are probably the principal species to be feared. Burroughs ('01, p. 137) writes that he has known the red squirrel to be caught by the black snake and successfully swallowed. In the Northeastern States, red squirrels and black snakes both frequent stone walls, and it is here that the snake would most frequently take its prey.

Mr. W. DeW. Miller has kindly shown me the record of an instance where he removed a full grown red squirrel from the stomach of a rattlesnake (*Crotalus horridus*) which was taken at Beaufort Mountain, New Jersey, on August 3.

Birds. The red squirrel has become notorious as a nest robber, more so perhaps than is its due; but there are many other ways than this in which the squirrel's life is more or less intimately associated with that of the birds, which share with it the trees and the ground. Let us examine first the evidence showing that the birds are the gainers and the squirrel the innocent sufferer. It is rare that sympathy is expressed for the red squirrel that loses its life because of the feeding habits of birds; yet a number of raptorial birds are its enemies, as evidenced by the fact that red squirrel remains have been found in the stomach of the marsh hawk, the goshawk, the red-tailed hawk, the red-shouldered hawk, and the broad-winged hawk (Fisher, '93, pp. 29, 45, 50, 64 and 81).

The stomach contents of hawks examined by Mr. W. DeW. Miller give the record of a few red squirrel captures. Mr. Miller's notes, which he has kindly allowed me to make use of, showed the absence of red squirrel remains from the following: goshawk, 21 stomachs; marsh hawk, 15 stomachs; duck hawk, 18 stomachs; sparrow hawk, 18 stomachs; red-shouldered hawk, 27 stomachs; sharp-shinned hawk, 199 stomachs; rough-legged hawk, 9 stomachs; and pigeon hawks, 10 stomachs. In two out of 40 red-tailed hawk stomachs, red squirrel remains were found. These hawks were taken in September and November, in Sussex County, New Jersey. Red squirrel bones were found in three of 35 Cooper's hawk stomachs. These hawks, also, were taken in Sussex County, New Jersey, in September and October.

Even the small sparrow hawk has been known to eat a red squirrel, as recorded by Seton ('09, p. 331) who writes that "A male sparrow-hawk was brought to me. In its stomach was a young red squirrel and a song sparrow. . . . Possibly the sparrow-hawk was seeking for a home when it discovered the squirrel's nest with the young one, and yielded to temptation." The squirrel shows fear of hawks, too, as shown by the observation of Klugh ('18, p. 11): "Upon two occasions when a hawk flew over, and upon another when it caught a sound like the scream of a hawk, the squirrel 'froze', remaining absolutely motionless for three minutes or more. As soon as it moved, it exploded into a loud and long continued chatter."

Owls rarely are active during those hours when the red squirrel is outside. In consequence it is little bothered by these birds. There is, however, record of an arctic horned owl, collected November 23, that had taken a red squirrel (Preble, '08, p. 372); and Mr. H. E. Anthony has found a pine squirrel in the stomach of a western spotted owl taken at Portland, Oregon, September 7. Fisher ('93, p. 152) records red squirrel remains in the stomach of a barred owl.

That gulls are enemies of swimming squirrels is suggested by B. F. Howell ('11, p. 521) who writes that squirrel skeletons are commonly to be found on Hogback Island, Moosehead Lake, Maine, where there is a large nesting colony of gulls.

Some birds successfully rob the red squirrel of his stored foods while others attempt to do so but fail. Klugh ('27, p. 26) relates: "A third phase of this relationship is that some birds such as the white-breasted nuthatch, downy and hairy woodpeckers, bronzed grackle, blue jay, and house sparrow, rob the red squirrel of food it has stored in the forks of trees. Both the squirrels I have had under observation lost a large part of their stored food in this way, not so much because most of the food was eaten by the birds, but because the birds in attempting to eat it knocked piece after piece of food out of the forks. Both these squirrels were frequently called upon to defend their stores against these marauders and when two or more of the birds came into a tree at once they had a very busy time, chasing one and then another. In chasing these birds the squirrels showed wonderful agility and many times could, I believe, have caught one of the birds if they had so desired, but in such cases they always jumped short so as not to actually alight on the bird."

The half-tame red squirrel known as Bismarck, which was under the observation of Walton ('03, pp. 93-94), defeated the would be robbers, as here quoted: "For years Bismarck and the blue jays have matched wits. After nesting, the blue jays would flock to the cabin and impudently appropriate all the food around the trees. Bismarck seemed to know that it was useless to store food longer in this way, so he would bury it beneath the pine needles. The jays were soon on to the trick. When I threw a piece of bread to the squirrel he would start at once to hide it, while the jays would follow him, keeping in the trees, just out of reach. The moment he left the jays would fly down, dig out the bread and carry it away. It often happened that Bismarck would fool the robbers by pretending to bury the bread. He would dig a hole, cover it over and pat down the pine needles, but would run away with the bread in his mouth. While the jays were scratching the pine needles right and left in a useless search, Bismarck would hide the bit of bread

and return to the dooryard for more. He was not so particular if the food was wheat bread, but if it was his favorite food, doughnut, the jays were fooled every time."

"Twice last summer," writes Walton (op. cit., p. 68), "I saw a red squirrel pounce on a young towhee bunting, but both times he let the bird go without loss of a feather. It was evident that he did not intend to injure the bird, but merely desired to frighten it away." Further, Walton (op. cit., p. 249) writes, "Ten crows made bold by hunger attacked Tiny and tried to take possession of a loaf of bread. The squirrel never flinched, but stood over the bread and whenever a crow got over the deadline, filled the dooryard with feathers. . . . The black rogues were obliged to retreat when Tiny got downright mad. When the fight began Tiny did not try to hurt the crows. He would run at one and allow him to hop into the air and take wing. It appeared to me that Tiny was just scaring the crows away. When he found that they were in earnest, he got mad and made the feathers fly, and the crows had to leave to save their lives."

A different reaction on the part of this same squirrel is also described (op. cit., pp. 240-242): "Tiny was not always full of fight. He formed a friendship for a young towhee bunting after a singular encounter. The bunting was eating from a loaf of bread, which was staked down in the door yard, when Tiny appeared. The squirrel thought that the bird would run away, but instead the latter set its wings and lowered its head in preparation for battle. Tiny was astonished. He sat up, folded his forepaws on his breast, and looked on the gamy little bunting with wide eyed wonder. The bunting soon turned to the bread. Tiny brought his forepaws down hard on the ground, evidently to frighten the bird. Again the plucky little bunting set its wings and lowered its head. Again Tiny sat up and looked the fellow over. This time there was a comical expression on the face of the squirrel that said as plain as words could tell that he appreciated the situation. That he admired the pluck of the bunting was evident by his action. He crept quietly to the opposite side of the loaf of bread and allowed the bunting to eat unmolested. After this the two would eat together whenever they chanced to be in the door yard at the same time.

"Tiny did not allow other buntings near his food, and I thought he would forget his bird friend when the buntings returned in the spring migration, but not so, he knew his friend at once, and chuckled some kind of a greeting while the bunting said something in bird language that seemed to my ears to express joy."

Cram ('99, p. 197) writes, "I have never known him [the red squirrel] to take part in the general outcry against a hawk or owl . . . but let him catch a glimpse of an unoffending partridge quietly gathering berries or scratching among the pine needles, and he immediately pretends to fall into an utterly uncontrollable rage. He slowly approaches the bird with short scratchy starts, down the tree trunk, keeping on the opposite side as much as possible, and peering out from behind the rough bark and protecting branches as if fully aware of his danger and determined on not exposing himself more than necessary, and ever and anon retreating, panic stricken, back into the shadow, to renew the attack from an opposite direction, barking huskily." Specific instances to show that the squirrel was aware of the nature of the animal that caused his excitement are not given.

Roberts ('22, p. 215) records having watched a titmouse on several trips

gather hair from the tail of a wide awake red squirrel, without any protest on the part of the squirrel.

There may now be considered the large number of cases in which the squirrel is seen to be the gainer and the birds the losers. By far the greater number of these refer to the destruction of the eggs and the birds. The one case of this kind that I have observed happened as follows: While sitting in my camp in a pine grove near Petersham, Massachusetts, about five o'clock one evening early in July, I heard a heavy object fall to the ground some thirty feet away. It had apparently dropped from the crown of a sixty foot white pine. In a moment an immature red squirrel was seen hurrying down the trunk. On the ground it immediately started foraging for something. The first thing to arrest its attention was a prune stone, which it carried a short distance up the tree and opened to get at the contents. Turning around on the branch on which it sat the squirrel pushed this seed into a crack in the rough bark. Returning to the ground, it picked up some larger object, which it carried by mouth to another pine nearby. Thirty feet up this tree, in the fork of a branch three feet from a trunk, the object was firmly fixed, and left. The squirrel descended and disappeared. On examination I found this stored object to be a nestling bird, bitten through the neck and dead, though yet warm. On the ground within two feet of the place where this bird had been picked up I found another similar nestling, with the head largely eaten, as were small areas of flesh on the wings and back. Whether this nestling was left on the ground because the squirrel was no longer hungry, or because it had a bad memory or a guilty conscience I can not guess. The young birds proved to be the black-throated green warbler.

On another occasion I found the wing feathers of a gray colored fledgling in the midden heap of a red squirrel, but I have no proof that the squirrel was the guilty one in this instance.

The red squirrel would seem to have a particular liking for robins, if one were to judge alone by the number of published accounts of its depredations on this species. Fisher ('96, p. 197) writes: "Repeatedly I have seen them [red squirrels] eating young robins and have killed several while attempting to plunder the wren boxes near the house." Mearns ('79, p. 172) records having seen a red squirrel kill a young robin in a nest, whereupon it was driven away by one of the parent birds. Kirtland ('38, p. 177) says that he has seen the squirrels destroy a whole brood of robins, and Seton ('c9, p. 322), that in June, 1906, at least three robins' nests in his garden were rifled of newly hatched young by red squirrels. Brayton ('82, p. 108) and the Finleys ('25, p. 152) give evidence of similar nature, and also of egg eating. Thoms ('22, p. 200) and Merriam ('84, p. 214) mention other instances of attack by the red squirrel on robins. The fact that robins and squirrels live near houses where food is scarce and they are likely to be observed must account for the preponderance of this species in the reports.

But other birds also suffer. For example a red squirrel was seen by Thoms ('22, p. 206) throwing young orioles from their nest, though the squirrel did not in this instance eat the birds. In the same place he records having seen a red squirrel pounce upon a mourning dove as she sat upon her nest. The bird struggled vigorously and escaped, but the squirrel ate her eggs. A chickaree

eating the flesh from the shoulders of a fledgling flicker was interrupted by Seton ('09, p. 322). Gibson ('83, p. 85) speaks of a red squirrel being repulsed in its attempt to rob a woodpecker's nest by a blow from the bill of the parent bird.

The destruction of a family of young bluebirds is recorded by B. S. Bowdish (Klugh, '27, p. 24) who writes that the squirrel devoured the brain of each nestling and dropped the carcass to the ground. He also found a red squirrel occupying a cavity in which a nuthatch had been building its nest a week before.

Merriam ('84, p. 215), without giving the details, says that he himself has known the red squirrel to rob the nests of the red-eyed vireo, the chipping sparrow, the robin, the Wilson's thrush, and the ruffed grouse.

Guides in the Adirondacks have frequently expressed to me their opinion that red squirrels commonly rob the nests of ruffed grouse. But none of these men had any conclusive evidence to offer, and while the squirrel may not be wholly guiltless in this matter it should not be convicted merely on circumstantial evidence of rather feeble nature.

Practically all species of northern warblers, vireos, thrushes, chickadees, nuthatches and others are numbered among the red squirrel's victims, according to Nelson ('18, p. 455), who omits specific instances.

From the foregoing records one might be led to conclude that the red squirrel is an habitual bird destroyer; but there are a number of other observations that tend to prove that this habit is at most only occasional and that more probably the habit is limited to individuals among squirrels, which prey on birds when other food is scarce, or after they once have had a taste of animal food of this kind. For example, Thoms ('22, p. 206) states that the two cases of nest robbing cited above are the only ones that have come to his notice in a total of twenty years' observation. He concludes that unless squirrels are overabundant they do no harm to the bird population, which easily recovers the relatively small losses incurred. Seton ('09, p. 322) quotes William Brewster's account of a squirrel which daily leaped over a robin's nest, but did no harm to the eggs or the young. Seton also mentions a family of five red squirrels living in a grove of six or seven small trees near his house, which left unmolested the nest of a yellow-throated vireo, though they must have seen it. Klugh ('27, p. 25) writes that in twenty-five years' ornithological experience, and in eight years' rather intensive study of the red squirrel, he did not come across a single instance of depredation of a bird's nest by the red squirrel. On the other hand he recorded three instances where broods of robins were successfully raised in locations which red squirrels visited every day. J. E. Pelcher, a fire lookout on Hamilton Mountain, New York, has informed me that a bird which nested in a spruce tree immediately in front of his cabin successfully raised its brood though red squirrels were numerous in the vicinity at the time. On one occasion he saw a squirrel actually run up to the nest and apparently scrutinize the fledglings for several minutes.

For the six years of his residence at Lake Placid, New York, Jacques Suzanne, an explorer, has looked for squirrel attacks on nesting birds, their eggs or their young, but found none. He tells me that he has had as many as fifty nests under observation in trees and on the ground where squirrels could hardly have overlooked them, yet he found no instance in which harm had been done.

Walton ('03, pp. 69-70) writes: "It was always a mystery to me why the birds were not afraid of the red squirrel. Let a hawk, an owl, a weasel, a cat, a snake, or any of the animals known to prey on birds, enter my dooryard while birds were rearing their young and the wildest alarm would prevail so long as the intruder was in sight. The red squirrel can come and go without a protest, which proves that the birds do not regard him as an enemy.

"Whenever I have detected a squirrel investigating a bird's nest it has turned out that curiosity was the motive.

"A pair of chickadees nested in a box that I had placed in an oak tree, and a squirrel that spent most of his time in the door yard made it his duty to investigate the nest several times a day. He did not harm the young birds and the old birds did not fear him.

"While I was watching a red-eyed vireo's nest last season I saw a red squirrel run out to the nest, stretch his full length on the limb (it was a very warm day), and look down at the young birds that were squirming about in their confined quarters. I counted ninety-six before he left, and I did not begin at first. I think he was on the limb fully two minutes. These young vireos were not molested, for I saw them leave the nest when full fledged.

"I have record of an oven-bird that nested at the foot of a pine tree which contained a red squirrel's nest. Four young squirrels were reared in a leafy nest in the top of the pine, and three young oven-birds in a domed nest on the ground."

Walton (op. cit., p. 98) further lists a total of nineteen nests representing ten species, namely, chestnut-sided warbler, black-throated green warbler, oven-bird, vireo, Canadian warbler, robin, towhee, catbird, Wilson's thrush, and indigo bunting, situated in the vicinity of his cabin, every nest of which was probably known and visited by the red squirrels there found, yet not one was disturbed by them. He (p. 247) states that for fifteen years in Maine and eighteen on Cape Ann he has no record of the red squirrel robbing birds' nests.

Cram ('99, p. 200) writes that in the spring he has seen a red squirrel persistently chasing pine finches and redpolls about the top of a gray birch, putting all his agility into play in his endeavor to catch them, creeping towards them cautiously and cat-like, and springing out suddenly when he fancied himself near enough. The birds, however, always slipped away just in time to save themselves. Cram interprets the squirrel's behavior as play.

A strange association with a saw-whet owl is related by T. A. Gentry (Coues, '74, p. 317), who describes the two as living in the same hole in a hollow oak tree. They were seen to enter together repeatedly. Seton ('09, p. 328) suggests that the squirrel came there to feed on the dead mice or small birds which are often stored in one corner of the owl's nest. Probably the bird derived no benefit from the association. He further observes that in the spring the squirrels become almost parasitic in their relations to the sapsucker, which they follow in quest of sap.

"Summing up this matter," writes Klugh ('27, p. 25), "the facts appear to be as follows: The red squirrel does, more or less frequently, eat both birds' eggs and young birds. People who happen to witness such attacks are usually interested mainly in birds, and often especially in the particular pair whose nest is raided, so

that the occurrence makes a deep impression. Any such estimate as 'each squirrel destroys 200 birds a year' [Nelson, '18, p. 455] is, to say the least, a gross exaggeration, as at this rate the number of birds in localities where squirrels are abundant would be seriously reduced, which is not the case. [Hornaday, '13, p. 79, writes that in the New York Zoological Park, squirrels were so numerous as to drive out the wild nesting birds.] Birds and squirrels have existed together in North America long before man came on the scene, and the settlement of the country has not rendered conditions more favorable to squirrels and less so to birds, but, if anything, the other way around. It is probable that only certain red squirrels are bird-eaters, just as only certain tigers are man-eaters and such individuals should be destroyed as soon as evidence against them is obtained."

Such a rational viewpoint must without doubt be adopted in the case of the red squirrel, in the light of all known facts. It is unfortunate that such opinions as, "It may eventually become necessary to outlaw them whenever found" (Nelson '18, p. 455), have gained such wide acceptance. It is as the Finleys ('25, p. 152) write: "Not far away is a neighbor who insists that all robins should be killed because they eat his cherries and strawberries. Another wants a bounty on moles that are such a pest in his garden and lawn. Another advocates the killing of hawks, owls, and cats." The wild creatures act as a system of checks and balances and the fact that animals which are known to be useful and attractive to man and utilized as food by other species can never justify the extermination of these others.

Carnivores. Several of the carnivores prey upon the red squirrel. It is written by many authors (Merriam, '84, p. 212; Bell, '98, p. 78; Seton, '09, pp. 330-331; Klugh, '27, p. 23, and others) that the marten is its principal enemy in the more remote regions. I have, however, been unable to find in the literature a single detailed record of a marten catching or eating a red squirrel. But Jedd Rossman, of North Elba, New York, for sixty years a guide in the Adirondacks, asserts that he has found places in the snow where marten have fed on red squirrels, consuming everything but the head. He adds, however, that since marten are now scarce in the Adirondacks they no longer act as a check on the red squirrel population. Tim Crowley, of Piseco, New York, a trapper of marten for many years, does not think that this carnivore catches the red squirrel very frequently. But doubtless the marten often does catch squirrels in a fair chase, because of its own exceptional agility in the trees. In those regions where the marten is yet fairly common the red squirrel probably exerts an influence on the marten population fully as great as that of the marten on the squirrel population.

The fisher is probably incapable of catching a red squirrel in a fair chase, and Bell ('98, p. 78) credits it with being a minor enemy of the chickaree. The scorched body of a red squirrel is, however, the finest bait obtainable for fisher trapping, according to Jedd Rossman. Bell ('98, p. 78) lists the mink as an enemy of the red squirrel and mentions an instance where he had two of these animals together in the same cage. At first the squirrel displayed great courage and agility and seemed to defend itself successfully against the attacks of the mink; but the next morning it was found dead, with its throat cut.

Dice ('21, p. 26) saw a red squirrel in a struggle with a half grown mink, on the banks of a stream in Alaska. The frantic screaming of the squirrel led him to suspect victory for the mink.

Weasels also, because of their ability to enter small holes, are credited by Seton ('09, p. 331) and Bell ('98, p. 78) with preying upon the red squirrel.

The lynx (Bell, '98, p. 78) and the bobcat where they occur in its territory may safely be considered enemies of the red squirrel. The domestic cat is likewise a successful squirrel catcher, as I have personally several times witnessed. Burroughs ('01, p. 137) declares that his cat knew well the taste of squirrel flesh.

The fox on the contrary probably rarely or never secures a red squirrel. But Cram ('99, p. 221) expresses the opinion that the chickaree is among the first arrivals after a fox makes a kill, and that it will dispute with a crow and the blue jay whatever is left of the feast.

Other rodents. Among the Muridae the red squirrel doubtless competes in some degree with the white-footed mouse, and possibly with some other species, for certain food supplies. Seton ('09, p. 332) has suggested that the deer mouse in its turn taps the red squirrel's hoards.

As an experiment I placed an adult male *Peromyscus* in a cage with a pair of red squirrels. One of the squirrels twice lunged at the mouse when it was first admitted into the cage and happened to come too close. The mouse evaded the lunge both times and thereafter ran as it pleased over the tails of its cage mates. For several days I kept the three together; and the mouse even shared the unlined nest box which was placed at the top of the three foot cage.

A wharf rat, according to Walton ('03, pp. 238-240), trespassing on the private feeding ground of a small red squirrel, was attacked and successfully driven away by the squirrel. The squirrel was none the worse for the encounter, while the rat either died from the effects of the squirrel's savage bites, or left the vicinity in disgust.

In the southern part of its range the red squirrel is in competition for food with the gray squirrel, the fox squirrel, the flying squirrel and the chipmunk, while in the western part of its range other species of squirrels also enter into such competition, at least with regard to certain kinds of food. The red squirrel being, however, the most adaptable among these species and capable of including the widest variety of food in its diet, is able successfully to cope with the others wherever they occur.

The chipmunk shares the hazelnut crop with the red squirrel, and to a lesser extent the fruits of other shrubs and trees. Though I have seen both species gathering hazelnuts from the same small thicket at the same time, with no evidence of hostility between them, I have, however, a record of one disastrous encounter. Richard Gill of Lake Placid, New York, told me that he and a friend saw a red squirrel pursue a chipmunk that had ascended a tree and, overtaking it, seized it by the back of the neck. The two fell a short distance to another limb, whereupon the squirrel released his hold and disappeared. Mr. Gill picked up the chipmunk which had fallen to the ground and found it quite dead, with no other injury than that to its neck.

A female ground squirrel of the genus *Callospermophilus* which I kept as a captive in the same cage with a pair of red squirrels, dispossessed these of their nest box and for two days held the supremacy while the two squirrels sought shelter in a dry part of the cage.

The flying squirrel probably comes but little in personal contact with the red squirrel, since its hours of activity are usually quite different. It would seem, however, not improbable that the red squirrel at times might contest with his more delicate relatives the possession of a nest hole. Many of their foods also are the same. The population of one probably thrives in part at the expense of the other species.

The fox squirrels are apparently being driven out of their home areas by the red squirrels near Sheridan, Indiana, which are here extending their range, according to Walker ('23, p. 128). Because of their evil disposition toward the fox and the gray squirrels, red squirrels were exterminated on the University of Michigan campus (Wood, '22, p. 18).

Gray squirrels. The red squirrel is so generally given to pursuit of the gray squirrel that it seems better to record the exceptions to this behavior, rather than the rule. Johnson ('18, p. 54) refers to five black squirrels and one red squirrel working together amicably, one September morning, in a group of hickory trees. In another instance, however, in the same locality, a red squirrel gave chase to a black squirrel: "Round and round the trunk they went. The black punished unmercifully. Unable to withstand so furious an onslaught the black squirrel rushed to the end of a branch and took a wild and flying leap into the next tree. Away he sped through the treetops, leaving the victor to hurl his contempt in characteristic red squirrel fashion." Hornaday ('13, p. 79) declares that before being thinned out, the red squirrels were driving the gray squirrels away from the New York Zoological Park. Walton ('03, pp. 74-76) writes: "The gray is no match for the red in a tree top in a trial of speed. He usually keeps to the ground where his long leaps give him the advantage over his fiery little foe. Many a sprinting match of this kind takes place in my door yard. If a red surprises a gray squirrel stealing food he sounds his war-cry, and in a mad rush is on to the gray before he can make off with the bit of food which he has appropriated. The gray, finding that he is hard pressed, runs around the cabin with the red hot at his heels. Round and round they go, the gray silent, the red yelling like a little demon. When the gray has had several narrow escapes, he drops the food and retreats unmolested.

"In all my years of observation once only have I known a gray squirrel to fight a red. I think it was hunger and desperation that induced the gray to fight. The gray was an old male, certainly three times as large as a red. The latter was an old male, and had held the door yard for several years against all comers. He was a sagacious, grizzled old warrior and I named him Bismarck. The fight took place in my door yard. It was a bloody battle for bread on a cold drizzly day in midwinter. The gray was whipped inside of three minutes. The snow was crimsoned with his blood and when he fled he left a bloody trail behind. At no time was there a ghost of a chance for him to win. The muscular energy of the red was astounding. His movements were too quick for the eye. While the fight lasted all I could see was a bounding mass of red and gray. The red squirrel did not appear to be severely wounded, anyway he remained out in the cold and rain to lick his wounds.

"From my observations I find the reds seldom chase the grays unless the latter enter territory which the reds claim the right to hold and protect."

A case in which a gray squirrel was occupying a nest box usually used by a known red squirrel, suggested to Seton ('09, p. 336) that the gray might rarely be victor.

The red squirrel is reputed to castrate the gray squirrel when pursuing this larger squirrel. The truth of the matter seems still obscure. Klugh ('27, p. 24) quotes Professor Manley Baker, as saying that "he had actually seen a red squirrel seize the scrotum of a gray squirrel and tear it open, on at least a dozen occasions. He did not think the act was the result of a deliberate attack for that purpose, but that the red squirrel seized and hung onto the most posterior part, aside from the tail, of the fleeing gray squirrel's anatomy. Professor Baker also stated that he had shot more than forty gray squirrels which had been castrated."

Richard Gill of Lake Placid maintains that he has seen near Wilmington, New York, red squirrels which pursued gray squirrels and nipped them in the scrotum; and that he has shot grays which had been castrated. Similar views are said to be common among hunters.

Without denying that the red squirrel occasionally may castrate the gray or at least bite it in the scrotum, it should be questioned whether all the reported cases of castrated grays are reliable. The botfly larva (*Cuterebra emasculator*) may possibly produce this alleged result in some cases, as suggested by Rowley ('02, p. 36). It is my opinion that most of the supposedly castrated squirrels have merely been males in which the testes were in the abdominal cavity, or that the observer, in some cases at least, had failed properly to distinguish between the sexes. In some of the instances reported the testes may not yet have descended into the scrotum because of immaturity of the individual, while in most of them it is probable that the animal had been taken after the close of the breeding season, when the testes are normally withdrawn into the abdominal cavity. There are also other possibilities. Rats are known to possess the power of retracting the testes during fighting periods. Possibly, the gray squirrel, too, has this power, and exercises it when frightened or when fighting. Seton ('09, p. 336) is probably right in branding at least most of such reports as, "an ancient, picturesque, and sanguinary myth."

Among farmers one occasionally hears mention of squirrels that appear to be crosses between red and gray species. Such a case is reported by Shufeldt ('20, p. 40) who writes: "Mr. C. L. Holmes of Waterbury, Connecticut, has called attention to the following facts in regard to hybridization of the red and gray squirrels: 'In 1874 or 1875, like most boys of twelve or thirteen I was very fond of pets and spent quite a little of my time trapping squirrels, both red and gray, which were very abundant around my father's house. One day I found in an old-fashioned spring door wire rat-trap, a squirrel which my father and we boys declared must be a cross between the red and the gray. It was about half way between the two in size, and had a red tail and a gray body; white underneath and a red stripe between the back and the belly. Its head was shaped like a red squirrel's and had a little red on it.'"

Very old red squirrels often approach gray squirrels in color, and young gray squirrels may at a distance be difficult to distinguish from red squirrels. Probably all such cases of "hybrids" are explainable on this basis.

RELATION OF THE RED SQUIRREL TO THE FOREST

The red squirrel is an animal of the forest. It is dependent on the forest for food, for shelter and for safety. In many ways the squirrel affects the perpetuation of the forest and because of this is of marked economic interest over the greater part of its range. Because of its habits of eating the seeds, buds, flowers, leaves and bark of trees, and of its occasional carnivorous proclivities which cause it to take the lives of certain insect eating birds, the squirrel is in some quarters considered a foe rather than a friend of the forest. Less spectacular, though in my opinion far more general and important, is the rôle the chickaree plays in tree planting, in insect destroying and in filling an important niche in the maintainance of the balance of nature.

The seed consumption of a red squirrel within its home range seems prodigious. Grinnell and Storer ('24, p. 207) estimate that each squirrel in the Yosemite region cuts at least 250 cones each season. On their estimate of one chickaree to each four acres of Canadian Zone in Yosemite there would be in the 250 square miles of this area about 40,000 squirrels. The annual harvest of fir cones here would then be 10,000,000 cones. Further (op. cit., pp. 208-209): "It might be expected that such wholesale consumption of fir seeds by the chickaree would be detrimental to the forest. But in those protected areas of the Yosemite region where man has interfered slightly or not at all with the natural balance and where tree squirrels have lived for untold generations, the forest appears to be of maximum density, and the young growth coming along is sufficient to effect full replacement of natural loss among the mature trees. Despite the heavy inroads which squirrels make, a certain percentage of cones always escapes their attention and remains on the trees; these cones mature and scatter their seed in usual fashion. Indeed the cutting off of a considerable percentage of the fruits (cones with seeds) by the squirrels may even be of benefit to the trees. It is analogous to the operations of an orchardist who thins out the fruit on his trees in order to obtain a moderate number of full-sized vigorous fruits rather than many small or average ones. Examination of the ground beneath pine trees patronized by chickarees shows, during the spring and summer, considerable numbers of cones in which the seed has matured naturally and has fallen before the cones themselves have dropped. It would appear that the squirrels merely harvest a surplus."

In all the spruce areas which I have examined in New York State and in Massachusetts there has been no lack of reproduction even though squirrels were abundant. Such stands were marked with numerous and large feeding middens, yet there were always many dried cones on the forest floor and others on the trees. Seedlings were abundant in practically all stands, abundant beyond the possibility of survival or the needs of replacement. The few stands deficient in seedlings (Fig. 19 shows one) were probably barren because of the aridity of the forest soil rather than because of any over-abundance of squirrels. In all other types of mature conifer stands examined, seedlings were invariably abundant.

The gray squirrel of California, according to Hofmann ('23, pp. 280-281), is condemned on the ground that it destroys practically all the sugar pine seeds. Hofmann points out, however, that past and present stands have become established not perhaps in spite of, but because of the squirrels. Reproduction now fails in

these regions presumably because of the unbalanced relation of squirrels to seed production. The number of trees has been reduced while the number of squirrels has increased due to the destruction of their natural enemies. Such conditions probably apply locally also to the red squirrel; yet over its range as a whole reproduction keeps pace with destruction wherever the activities of man and his domestic animals do not prevent it.

As noted before, a pair of my captive red squirrels, supplied only with apples and cones, consumed during one week of September the seeds of four hundred and twenty-two white pine cones. This number represents approximately the total crop of two fifty year old trees. It should not be supposed, however, that the squirrels would consume this quantity in nature, for many other kinds of food complement the pine seed diet of the red squirrel in September. Storage operations may, however, account for weekly quantities of cones in excess of those consumed by my captives. In the home range of one pair of squirrels under my close observation in the Harvard Forest, probably 90% of the white pine cones were cut, for few of the trees here bore heavily and these were intensively harvested. Yet in this forest where the dominant tree was the white pine there was an abundance of this species in all stages of reproduction. The forest has too close a stand of pine to produce good timber so that if here the squirrels were reducing the reproduction of pine they were distinctly benefiting the forest as a whole, and aiding nature in producing more quickly a mixed climax forest.

The consumption of quantities of mast in the southern parts of the squirrel's range is abundantly compensated by the planting operations of the chickaree.

The destruction of seeds of maple and elm, while vast in the total, is obviously in all ordinary cases insignificant in comparison with the prodigious quantities of seed production.

Bud destruction is of greatest harm to the trees, in such cases as I have described from the Harvard Forest and elsewhere, in stands of red, white and Norway spruces, larch and Scotch pine. In the case of larch the tree may be entirely denuded. The adventitious growth occurring along the trunk the ensuing spring is doubtless insufficient to maintain life for more than a short time in badly affected trees. In Scotch pine the tree may be so badly deformed as to assume a bushy appearance. The spruces suffer least and are, it seems, most commonly affected by the wasteful competition of two or more laterals vying for position as leader. It is probable also that there is a general retardation of growth due to bud loss.

In the Harvard Forest the greatest damage was done to plantations, entailing a heavy loss on the investment in the land and its slow-maturing crop. In natural forests the injury resulting from bud destruction appears to be negligible, except in some cases of spruce and of larch cuttings. No case of observable damage to any of the broad-leaved trees resulting from bud injury has come to my notice, though in one cutting of ash which I observed such injury may have caused defoliation of the tree at least until new buds could be formed.

Also the twigs of some trees are cut to a great extent, in the budding and the seed eating activities of the red squirrel. In a few instances, as in the larches, there may be little left of the tree but a barren pole and a few denuded large

branches. During the harvesting of cones, nuts, and the seed clusters of elm and maple, innumerable terminal twigs are cut, yet I have never seen a tree which visibly was affected by the loss. There must be growth retardation, but only in a small tree could this be a serious matter. Grinnell and Storer ('24, pp. 210-211) write of a chickaree (*S. douglasii albolimbatus*) which in obtaining twig tips for bedding material cut more than half of the terminal foliage of the particular tree on which it worked.

Barking of maples and other trees in ordinary circumstances results in little harm, for as Klugh ('27, p. 27) remarks, "the amount of bark which is eaten from any individual tree is usually small and a branch is girdled only in exceptional cases."

Eggs and young of insect-eating birds are sometimes eaten by red squirrels, as is well shown by the several records which I have given, yet the consensus of opinion is that the number of such depredations is relatively small, and, such being the case, they cannot be considered especially harmful so long as it remains to be demonstrated that the forest would be distinctly benefited if there were fewer insects of those principal species which these birds eat.

The greatest benefit to the forest attributable to the chickaree is the planting of trees, though there are also other qualities to commend this squirrel. The opinions of eleven forest supervisors of Colorado and Wyoming on the status of squirrels in relation to the forests, expressed in response to a questionnaire, were as follows (Silver, '24, p. 166): Three considered them beneficial chiefly on account of their large stores of select seeds which are of great aid to the Forest Service in the gathering of seed for their own planting projects; three thought that the squirrels actually helped reforestation by the distribution of seed; only one mentioned their æsthetic value.

The planting of seeds falls into two categories. First, there is the storing of the nuts singly or in small groups, a constant source of reproduction; and secondly, the storage of conifer seeds, probably of importance only following a forest fire or intensive lumbering operations. In the planting of nut trees the red squirrel by reason of its northern range and its greater tendency to hoard its stores probably plays a less important rôle than do the gray or the fox squirrels. Nevertheless there is a wide belt in the southern part of the chickaree's range where its mast burials undeniably are useful to man in advancing forest reproduction. Squirrels not only carry nuts into open areas and so initiate extension of the forest, but as Thoreau ('06, pp. 189-190) points out, they have a tendency to carry acorns and walnuts to dense stands of pine. The seedlings get a good start if the pine is cut over. When wind is carrying the pine seeds into the oak forests, the squirrels are carrying acorns into the pine. Furthermore, the tree species foreign to the locality have the advantage in that the soil for them is not exhausted. Thoreau also observes (op. cit., p. 199) that squirrels frequently drop nuts in open land, which accounts for the oaks and walnuts that spring up in pastures. On the other hand, nuts stored in hollow trees, under rocks or in logs cannot be of further direct use to the forest.

Of the planting of conifers Hofmann ('23, p. 281) states that "Research has determined that the even-aged stands of reproduction which occur over large

areas after forest fires are due to seed which was stored in the forest floor before the fire and retained its viability through the fire." In some places there were as many as 40,000 seedlings per acre resulting from rodent caches, where all litter and duff had been consumed by fire and no seed trees were left in the open. Further (op. cit., p. 282), it is observed, "The planting of seed in the mineral soil is also a decided advantage in the establishment of the seedlings in such localities. During the dry season the surface soil dries out to a point where the water content is less than the requirements of seedlings; consequently it is essential that the seedlings form deep root systems before the dry season. Seedlings in the mineral soil have a better chance to develop deep root systems than those that germinate on top of the duff."

The limit of planting distance from seed trees, by the red squirrel, is set by Hofmann (op. cit., p. 283) at three hundred feet in cut over areas, a distance that is certainly a conservative estimate. In open areas with stumps and logs scattered throughout it is my opinion that the planting distance would be much greater than in a barren pasture or in a completely burned area. The red squirrel does not commonly bury many seeds out in the open. It may, however, go out into such an area to feed and may drop seeds from a stump, accomplishing no more than would the wind in its normal dispersal of seed. Cones buried by red squirrels in situations where the soil is easy to dig are usually buried too deep to favor successful germination, and until controls are run with seed buried at varying depths, such plantings cannot be properly evaluated.

How useful the squirrel may be as an insect destroyer is as yet unknown. McAtee ('26, p. 416) credits arboreal squirrels with feeding commonly on scale insects and other tree pests. In the Adirondacks, where I found most of the balsam and spruce cones ruined by cone borers, the red squirrel may serve as a check on the spread of this pest by cutting down infested cones along with good ones. There may be a similar control, too, of the borers present in the cones of white pine. As a result of his observations on the gray squirrels feeding upon the oak gall (*Amphibolips conflucens*), Davis ('24, p. 91) suggested that the squirrels might be acting as a check on the increase of this gall.

RELATION TO MAN

As a nuisance. On occasion the red squirrel may become a local pest, because of its feeding habits. When its numbers become greatly increased and its food as a consequence scarce, the red squirrel is apt to find its way into communities where it may cause certain forms of injury to man's interests. Thus they were a serious pest in Leelanau County, Michigan, in the summer of 1921, damaging a considerable amount of the pear and apple crops and gnawing their way into several houses in search of food or shelter.

Gilpin ('70, p. 13) states that "The winter camps of the loggers become infested with them. The men have scarce left their camps for their work, than the silent rude structure is attacked by an army of invaders; every hole, every crack and orifice is pried into. An entrance is made, and perhaps, a half barrel of hard bread has been removed by these red pilferers before the men return for the night.

Hard biscuit, perhaps from its resemblance to nuts and beech mast, is a very favorite food. During autumn they approach the villages and gardens in numbers. I have counted seven in sight."

According to Jedd Rossman, of the Lake Placid Club, the guardians of estates on the shore of Lake Placid have considerable difficulty keeping squirrels out of the houses in winter. They are said to do much damage by chewing up blankets and other articles. At my camp on Valcour Island one squirrel developed the habit of coming early each morning to the larder in search of peanut butter. Each time it would pry the lid off the jar, sometimes knocking the jar off the shelf in the act. On one occasion it pushed a heavy can off the top of the peanut butter jar to get at the contents. Squirrels in previous years carried off soap, candles, candies, tomatoes and other objects from the camp. From a garden at Petersham, Massachusetts, a red squirrel not infrequently stole sunflower seeds. DeKay ('42, p. 62) writes that this squirrel feeds occasionally upon wheat, rye, corn and buckwheat, but that the injuries to the farmer must be very limited. Klugh ('27, p. 22) says that "It sometimes makes repeated visits to corn cribs and carries off considerable quantities of corn, and I have known a squirrel to carry off most of the grains in a small sack of wheat." Kennicott ('57, p. 68) also writes of corn being stolen, eaten and stored.

Considerable damage is done to the pear and apple crops in the squirrel's search for seeds, as noted by Fisher ('96, p. 197), Burroughs ('01, p. 11), Rowley ('02, p. 35), Stone ('08, p. 84), Hatt ('24, p. 399), and Klugh ('27, p. 17). Rowley (*loc. cit.*) adds that ". . . not being content with cutting enough to satisfy his immediate appetite he seems to take great delight in wantonly cutting off the growing fruit and allowing it to fall to the ground where it remains untouched."

Other garden fruits are eaten on occasion, too, as recorded by Klugh ('27, p. 17) on the report of A. H. Leim. These are green strawberries, green gooseberries, and white and red currants.

The trappers in the North are annoyed by the red squirrels which, according to Merriam ('84, pp. 211-212) and Dice ('21, p. 26), frequently spring their traps. Dice (*op. cit.*) says that the motive may be curiosity, for he never saw them disturb the bait, or any animal taken in the traps. Earlier (*op. cit.*, p. 25), however, he records the instance of a red squirrel storing a grouse head which had been used as bait in trapping weasels. On several occasions I have caught red squirrels in traps set and baited for other animals.

Mythology. Among the Indians there developed legends surrounding the red squirrel, just as was true with regard to most of the other creatures of the forests. One such legend has been recorded by A. L. Adams ('73, pp. 57-58) who writes: "There came a belief among the ancient Indians of New Brunswick that the squirrel had been an enormous animal, but that one day an old man of the tribe was asked by the Great Spirit, what he should most desire and he replied: 'To reduce the size of this giant squirrel [mike].' Whereupon he received the divine mandate and going forth from the council chamber stretched out his hand, when the squirrel shrank to its present proportions. Therefore the result has been that the little creature has ever since been querulous at the sight of man."

The chickaree served Longfellow, too, in his "Hiawatha," in which we read:

"Up the oak-tree, close beside him,
Sprang the squirrel, Adjidaumo,
In and out among the branches,
Coughed and chattered from the oak-tree,
Laughed, and said between his laughing,
Do not shoot me, Hiawatha."

In the Old World squirrels figured frequently in literature and in art, reference being chiefly to *S. vulgaris*. According to the University Society ('06, p. 147), in old Scandanavian legends the squirrel is represented as the messenger of the gods, who carried news of what was going on in the world among the other animals.

As a pet. The red squirrel rarely becomes wholly tame in captivity. Of a dozen which I have held for varying lengths of time only one ever accepted food directly from my hand, and none would tolerate handling. One individual, probably through a paralysis of fear, permitted me to touch it when it was in a very small cage, but would not tolerate further familiarity. My squirrels did well in captivity, but never seemed to feel at ease in their confinement. Most of the time they would be quiet and, when in pairs, peaceful among themselves. During feeding hours, however, each squirrel displayed the utmost selfishness. Of one pair in my possession one individual would invariably have to wait until the other was satisfied before venturing to the feeding floor. The animals were usually most active about sunrise, and noisy in their fights at that time. My captives spent most of their time in the nest boxes, or in nests which they constructed from cotton given them. None of them attempted to gnaw out. They accepted all food of kinds they were accustomed to in the native state, and many other similar kinds such as various nuts from other sections of the country. The squirrels at first rejected, but later learned to eat sunflower seeds and English walnuts. They never ate rolled oats, fresh sweet corn, either in or without the husk, nor would they eat green peas or beans.

Klugh ('27, pp. 6-8) quotes an account of a squirrel which was kept in captivity about nine years by Charles Macnamara. As was true of many of my squirrels, this individual also kept up a daily routine of exercise, including rapid dashes around the cage or over the surface of the wire netting. Evermann and Clark ('11, p. 67) record capturing a young squirrel which was allowed its freedom in a room, and became tame enough to run up and sit on one's shoulder. Hearne (1795, p. 385) wrote that "The beauty and delicacy of this animal induced me to attempt taming and domesticating some of them, but without success, for though several of them were so familiar as to take anything out of my hand and sit on the table where I was writing and play with the pens, etc., yet they never would bear to be handled and were very mischievous, gnawing the chair bottoms, window-curtains, sashes, etc., to pieces." Spreadborough ('19, p. 62) found them easy to tame, and interesting pets. He writes: "We had one in a cage and my brother used to tickle it with a straw. It would roll and tumble and play like a young kitten, but only with my brother as the others were strangers to it." Merriam ('84, p. 218) considers them intelligent but unruly and destructive pets.

To obtain the best results the squirrels should be taken from the nest very young and given only the most gentle care in surroundings not likely unduly to excite them. If one has secured an individual with a gentle disposition one will be rewarded for any extra trouble by the results. The cages should always be large, supplied with a nest box, and preferably with a revolving drum in which the occupants may exercise.



Photograph by American Museum Natural History

Fig. 52. Headdress of Tsimshian Indian, made of six red squirrel skins. Skeena River district, British Columbia.

Food and fresh, clear water with freshly cut twigs of oak and other trees should be available to the animals at all times if they are to thrive and remain in the best of health.

As fur. According to Hearne (1795, pp. 385-386), "They [red squirrels] are an article of trade in the [Hudson Bay] company's standard, but the greatest part of their skins being killed in summer are of very little value." St. Hilaire and Cuvier (1824, Vol. III, pages unnumbered) somewhat later wrote that "the young Indians take in traps great quantities for their skin makes a very pretty fur and is

thus an object of commerce." Dice ('21, p. 26) says that a "child's parka (outer winter garment) of red squirrel skins was seen near Tanana [Interior Alaska] but the fur is not used to any extent by the Indians and is seldom purchased by traders." Richardson (1823, p. 188) also says that the fur is not used even by the Indians and certainly the skins play no part in the present international fur trade, for they are small, and the fur quite light.

The headdress of a Tsimshin Indian (Fig. 52) from the Skeena River district of British Columbia is in the collections of the American Museum of Natural History. It is made of six flat red squirrel skins, with tails extending up from the crown.

A Blackfoot ceremonial robe in the same museum is of tanned buffalo hide, painted yellow and decorated with the cased skins of red squirrel, brown weasel and white weasel; also with hawk feathers. Skins of the fox squirrel and of the gray squirrel, together with other objects, were used as hunting "medicine" by the Winnebagos. Probably also with other Indians the red squirrel was considered "good medicine."

As food. Few people use the red squirrel as a food, its small size as well as its flavor preserving it from such misfortune. In the east I have occasionally eaten red squirrels cooked in a stew, or fricasseed, and considered the meat quite palatable. In the Rockies, however, *S. fremonti* tasted too strongly of the pines on the seeds of which it fed to encourage my trying it a second time. DeKay (1842, p. 62), however, wrote of *S. hudsonicus* that its flesh was juicy and tender and generally preferred to that of other species. Similar testimony is found in the writings of a number of other authors such as Hearne (1795, p. 385), Richardson (1823, p. 188), Audubon and Bachman ('49, p. 128), and Evermann and Clark ('11, p. 7).

Methods of capture. The squirrel is easily shot or taken in steel or box traps. Traps may be baited with apple or any other palatable food that is not too abundant near the trap. In regard to its capture in the Hudson Bay territory, Hearne (1795, p. 385) wrote: "The common squirrels are plentiful in the woody parts of the country, and are caught by the natives in considerable numbers with snares while the boys kill many of them with blunt headed arrows. The method of snaring them is rather curious though very simple as it consists of nothing more than setting a number of snares all around the body of the tree in which they are seen and arranging them in such a manner that it is scarcely possible for the squirrels to descend without being entangled in one of them. This is greatly to the amusement of the boys."

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